AD-A021 890

AN EXPANDED VARICOMP METHOD FOR DETERMINING DETONATION TRANSFER PROBABILITIES

James E. Means

Naval Weapons Center
China Lake, California

December 1975

NWC TP 5789

An Expanded Varicomp Method for Determining Detonation Transfer Probabilities

by
James E. Means
Fuze Department

DECEMBER 1975

Naval Weapons Center
CHINA LAKE, CALIFORNIA 93555

Naval Weapons Center

AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

R. G. Freeman, III, RAdm., USN .... Commander
G. L. Hollingsworth .... Technical Director

FOREWORD

This document reports the development of a new VARICOMP technique and the details of the calibration and statistical analysis of several design and two VARICOMP explosives for use in evaluating safety and reliability of fuze explosive trains. The work was done by R. Stresau Laboratory, Inc., Spooner, Wisconsin, under contract with the Naval Weapons Center from July 1971 to July 1974. Funding was provided under ORDTASK ORD-035C-211/200-1/UF 32-352-501.

This report has been reviewed for technical accuracy by R. H. Stresau and M. E. Anderson.

Released by
R. A. BOOT, *Head (Acting)*
Fuze Department
24 August 1975

Under authority of
G. L. HOLLINGSWORTH
Technical Director

NWC Technical Publication 5789, Part 1

Published by .... Technical Information Department
Collation .... Cover, 38 leaves
First printing .... 395 unnumbered copies

DEPARTMENT OF THE NAVY
NAVAL WEAPONS CENTER
CHINA LAKE, CALIFORNIA 93555

IN REPLY REFER TO
531/MK:mf
Reg 531-085-76
25 February 1976

ERRATA

NWC TP 5789

An Expanded VARICOMP Method for Determining Detonation Transfer Probabilities, by James E. Means, Fuze Dept.
December 1975

Naval Weapons Center
China Lake, California

It is requested that the following pen and ink changes be made on the above report.

Inside front cover, Publisher's statement: Change "NWC Technical Publication 5789, Part 1" to read "NWC Technical Publication 5789."

Figure 13, page 27: Under horizontal scale add "DONOR DIAMETER, MILS."

Figure 28, page 40: At top of curve X348 add "A"; in first line o: key in lower left corner delete "A".

A. B. Christman

A. B. CHRISTMAN
By direction

ib

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER NWC TP 5789	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) AN EXPANDED VARICOMP METHOD FOR DETERMINING DETONATION TRANSFER PROBABILITIES		5. TYPE OF REPORT & PERIOD COVERED Final Report July 1971 to July 1974
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) James E. Means		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Weapons Center China Lake, CA 93555		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS ORDTASK ORD-035C-211/200-1/UF 32-352-501
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Weapons Center China Lake, CA 93555		12. REPORT DATE December 1975
		13. NUMBER OF PAGES ~~71~~ 72
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Detonation Transfer Probabilities
Fuze Explosive Components
VARICOMP Method

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

See back of form

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

(U) *An Expanded VARICOMP Method for Determining Detonation Transfer Probabilities*, by James F. Means. China Lake, Calif., Naval Weapons Center, December 1975. 74 pp. (NWC TP 5789, publication UNCLASSIFIED.)

(U) VARICOMP (a term coined by J. N. Ayres for a method developed at the Naval Ordnance Laboratory, White Oak, in the 1950s and early 1960s) is a method for evaluating the interface between fuze explosive components in which it can be determined by statistical analysis and testing that the reliability and safety of a fuze explosive train can be predicted at high-confidence levels with a small number of tests. This is done by varying the sensitivity of different explosives that are then substituted into the explosive train of interest to determine the safety and reliability limits under a penalty test situation. For reliability tests the acceptor design explosive is replaced by a less sensitive VARICOMP explosive, whereas for safety evaluation a more sensitive explosive (PETN) is used.

(U) Under contract with the Naval Weapons Center, R. Stresau Laboratory, Inc., completed the sensitivity calibration of various design explosives and two different series of VARICOMP explosives (desensitized RDX). The work differed from earlier similar efforts in that each explosive was calibrated using donors of three diameters (50, 100, and 200 mils). One of the VARICOMP mixes has a sensitivity to initiation nearly independent of diameter, the other has a sensitivity to initiation highly dependent upon diameter.

CONTENTS

GLOSSARY

Acceptor. The explosive element that accepts the explosive output from a donor; that is, leads and boosters

Barrier. Usually a metal placed between the most sensitive element and the next element in an explosive train to prevent inadvertent initiation of the munition The barrier is removed when the munition Safety-Arming device is armed during flight Also called attenuator when used in the Small-Scale Gap Test (SSGT) and the Proportional Gap Test (PGT).

Booster. An assembly of metal parts and explosive charge provided to augment the explosive components of a fuze so as to cause detonation of the main explosive charge of the munition.

Calibration. The technique used for determining the shock sensitivity of an explosive material In the SSGT, Lucite attenuators of varied thickness are used between the donor and acceptor; while in the PGT, attenuators of aluminum and steel are used, the Bruceton test method is used to determine the 50% probability of fire, and statistical analysis is used to determine other probability-of-fire percentages

Decibang (DBg). A measure of the stimulus for the SSGT defined as: $X = 10 \log 1/g$, where X is the stimulus in decibangs (DBg) and g is the attenuator thickness (gap) in inches

Design explosive. The explosive material to be used in the final design of an explosive train

Donor. The explosive element that delivers an explosive charge to an acceptor, that is, detonator, squib, and lead

Explosive train. An explosive train is an assembly of explosive elements arranged in order of decreasing sensitivity Its function is to accomplish the controlled augmentation of a small impulse into one of suitable energy to cause the main charge of the munition to function

Fuze. A device with explosive components designed to initiate a train of fire or detonation in an item of ammunition by any action such as hydrostatic pressure, electrical energy, chemical action, impact, and mechanical time, or a combination of these

Gap test. Abbreviation often used for SSGT.

Lead. An explosive train component that consists of a column of high explosive, usually small in diameter, used to transmit detonation from a detonator to booster charge.

Mil. A unit of length equal to 0 001 inch.

Mixed response. In a Bruceton test, some of the explosive items detonate or respond at certain test levels, and some do not detonate; hence a mixed response.

NOL. Naval Ordnance Laboratory, White Oak, now Naval Surface Weapons Center, White Oak.

NOLC. Naval Ordnance Laboratory, Corona (since disbanded).

PAIDBg. Abbreviation for Proportional Aluminum Gap Decibangs denoting aluminum as the attenuator material.

Preceding page blank

Penalty test. By using a VARICOMP explosive, which is less sensitive than the design explosive to evaluate an explosive train, the probability that the item will detonate is reduced.

Proportional Gap Test (PGT). A variant of the SSGT used in the calibration of explosive materials. The major differences between the SSGT and the PGT are that (1) the SSGT uses brass, and the PGT uses Delrin to confine the explosive, that (2) the SSGT uses Lucite, and the PGT uses aluminum or steel as the attenuator between donor and acceptor, and that (3) the SSGT uses only 200-mil-diameter explosive columns while the PGT uses 50-, 100-, and 200-mil-diameter explosive columns.

Prototype. An item representative of the final design in which no more design changes are expected.

PStDBg. Abbreviation for Proportional Steel Gap Decibangs denoting steel as the attenuator material.

RDBg. Relative decibang has same value as decibang. Used to distinguish difference between old and new calibration schemes.

Sensitivity inversion. A phenomenon that occurs between two different explosive materials that differ either in composition or state of aggregation. The relative sensitivity of the two explosives can invert when used in sources of substantially different sizes.

Small-Scale Gap Test (SSGT). This test is an arbitrary configuration to study the transfer of detonation between small-diameter charges loaded into heavy walled cylinders. The initiating shock is varied by changing the thickness of Lucite interposed between the acceptor and donor. The acceptor charges are 1.5 inches long and 0.2 inch in diameter, loaded into 1.0-inch-diameter brass cylinders.

Surrogate. Substitute.

Trials. The number of tests performed to determine the safety or reliability of an explosive interface.

VARICOMP (VARIation of explosive COMPosition). VARICOMP is a method for predicting the detonation transfer probability of an explosive train by substitution of explosives of varied sensitivities for the design explosive. These substituted explosives, whose response have been calibrated relative to the design explosive, are used to measure the explosive drive inherent in the design system.

INTRODUCTION

VARICOMP as a Penalty Test

Because the establishment of required safety and reliability levels in fuze explosive trains would require sample sizes so large as to be economically prohibitive, most explosive train detonation transfer probabilities are determined by penalty tests. In a penalty test, a property of the system is modified to reduce the probability of the desired result. For example, to predict safety, a particular explosive train interface may be tested with a standard donor and a "more sensitive" acceptor; conversely, to predict reliability, a "less sensitive" acceptor material is used. If this probability is reduced sufficiently, it is possible to obtain mixed responses (that is, some fires and some no-fires) with samples of reasonable size and to develop data from which the mean value of the penalty and its standard deviation (as well as confidence bands) can be established. These estimates can be used in statistical extrapolation to estimate safety or reliability under the original design conditions. The VARICOMP (VARIation of explosive COMPosition) method, first described completely in a NAVWEPS report,[1] is a penalty test in which the variable property is the sensitivity of the acceptor explosive at an interface to be investigated. Special terms are defined in the Glossary.

Advantages of VARICOMP

As compared with other penalty tests (such as varying the thickness of the out-of-line barriers), the VARICOMP method has both advantages and disadvantages. The advantages include the alleviation of the interpretational problems resulting from the complexity of the relationships between each of the variables that can be used in other penalty tests of fuze trains. Another advantage of the VARICOMP method is that no mechanical alteration of fuze components is necessary. In addition to the saving of time and effort required for such alterations, the original VARICOMP method eliminated questions regarding the effects upon detonation transfer of fragments whose size, number, velocity, or flight pattern might be affected by such alteration. A third advantage of the VARICOMP method, as it has been used in the past, is that a series of surrogate explosives has been characterized with respect to mean sensitivity, estimates of the standard deviation, and the precision of these estimates.

[1] Naval Ordnance Laboratory. *VARICOMP, a Method for Determining Detonation Transfer Probabilities*, by J. N. Ayres and others. White Oak, Md., NOL, January 1961. (NAVWEPS Report 7411.)

The existence of these data makes it possible to estimate the reliability or safety of a system from the results of relatively few trials. In view of the high cost of developmental hardware, this makes the VARICOMP method particularly attractive for preliminary tests performed in early stages of development before a design is finalized. If neither the design explosive nor the surrogate has been calibrated, much of this economic advantage of the VARICOMP method is lost, since in addition to the VARICOMP tests of the prototype fuze, the two calibration tests are necessary. (In spite of this need, the VARICOMP method, which requires less prototype hardware, may still be less expensive if the prototypes are sufficiently costly.)

Disadvantages of Original VARICOMP

The most serious disadvantage of the VARICOMP method, as it has been used in the past, is that safety and reliability predictions are based on the assumption (in addition to those inherent in all penalty test interpretations) that the relative sensitivities of the design explosive and the VARICOMP surrogate are the same in the system under investigation as in the calibration test arrangement. Although the original description of the method, in recognition of the pitfalls inherent in this assumption, recommends the use of a calibration test arrangement as similar as is practical to the system to be tested, the availability of Small-Scale Gap Test (SSGT) data for so many explosives has encouraged many to ignore the admonishment. In most applications of the VARICOMP method by NWC and NOLC (where members of the RDX, Class A/calcium stearate binary system were used as surrogates for CH-6 in the evaluation of systems in which the donors were 190-mil-diameter detonators or leads), the assumption was quite valid. This is true since CH-6 is essentially a member of the above-mentioned binary series (and behaves as such). It is also true since the leads and detonators that served as donors in previous fuze systems were similar, at least in diameter, to those of the SSGT (200 mils).

Recently, however, smaller detonators have increasingly been used as donors and other explosives, notably PBXN-5 and HNS-1A, serve as acceptors. Such systems so differ from the SSGT that they invert the relative sensitivity of members of the existing binary series with respect to some design explosives. Such inversions invalidate the above assumption, upon which safety and reliability predictions from VARICOMP data are based. The most important source of such inversions are size effects. As donors become smaller, the shock waves induced in the acceptors become more sharply divergent so that, to be self-sustaining, more vigorous reactions are necessary. Since the reaction rates of explosives, as related to shock strength, vary with state of aggregation as well as composition, inversions of relative sensitivity (as source sizes are changed) have been observed between explosives of the same or similar composition but with different particle size and even between samples of the same lot of explosives pressed at different densities.

Another source of sensitivity inversions is the effect of the shock impedance (Hugoniot) mismatch between the transfer medium and the acceptor. The relatively large range of the shock impedance of various explosives and the sharp variation of this property with loading density of any given explosive are reflected in large differences in strengths of shock waves transmitted to the explosives through various transfer media. The media between donor explosive and acceptor explosive also vary greatly in shock impedance, that of steel, for example, is eight times that of polymethylmethacrylate (chemical term for Lucite).

The New VARICOMP

Reported herein and by R. Stresau Laboratory, Inc.,[2-7] is an effort to develop a variant of the original VARICOMP method in which the effects of transfer media and component size variables (and resulting sensitivity inversions) can be taken into account. With this objective, each explosive at each loading density of interest was characterized by Proportional Gap Tests (PGT) where donors of three sizes (50, 100, and 200 mils in diameter) and two transfer media (aluminum and steel) were used.

The Stresau reports include an account of the development of the PGT and detonation transfer sensitivity data obtained therewith for various explosives. These include PBXN-5, Type I, PBXN-5, Type II, CH-6, HNS-IA, PETN, and two VARICOMP mixes.

CALIBRATION SYSTEM FOR NEW VARICOMP

The general arrangement of the calibration system is shown in Figure 1 and was used for all the design explosives and VARICOMP mixes calibrated. See Appendix A for detailed sketches of all components.

Donor Initiation

The explosive reaction in the donor initiators is initiated by ohmic heating of the stainless steel foil in contact with the upper surface of the lead azide initiator charge when an electric current flows through the very small contact area of the needle electrode into the foil. This initiator, with

[2] R. H. Stresau. *Development of the VARICOMP Method, Expansion of Applicability (To Determine Detonation Transfer Probabilities With Reduced Dependence Upon System Variables). Part I(c). Calibration of CH-6 as a Design Explosive.* Spooner, Wis., R. Stresau Laboratory, Inc., 1974. (Report RSLR 74-1 for Naval Weapons Center, China Lake, Calif.)

[3] R. H. Stresau. *Development of the VARICOMP Method. Expansion of Applicability (To Determine Detonation Transfer Probabilities With Reduced Dependence Upon System Variables). Part 1. Calibration and Characterization of PBXN-5 as Design Explosive.* Spooner, Wis., R. Stresau Laboratory, Inc., 27 December 1972. (Report RSLR 72-7 for Naval Weapons Center, China Lake, Calif.)

[4] R. H. Stresau. *Development of the VARICOMP Method, Expansion of Applicability (To Determine Detonation Transfer Probabilities With Reduced Dependence Upon System Variables). Part 3. Calibration of RDX/Calcium Stearate Binary System for Use as "VARICOMP" Surrogates.* Spooner, Wis., R. Stresau Laboratory, Inc., 14 February 1973. (Report RSLR 73-1 for Naval Weapons Center, China Lake, Calif.)

[5] R. H. Stresau. *Development of the VARICOMP Method, Expansion of Applicability (To Determine Detonation Transfer Probabilities With Reduced Dependence Upon System Variables). Part 5. Calibration of PETN for Use as a Surrogate for PBXN-5 in Safety Tests.* Spooner, Wis., R. Stresaul Laboratory, Inc., 8 May 1973. (Report RSLR 73-2 for Naval Weapons Center, China Lake, Calif.)

[6] R. H. Stresau. *Development of the VARICOMP Method, Expansion of Applicability (To Determine Detonation Transfer Probabilities With Reduced Dependence Upon System Variables). Part 2. Formulation of VARICOMP Mixtures With Minimum Dependence of Sensitivity Upon Donor Diameter.* Spooner, Wis., R. Stresau Laboratory, Inc., 14 June 1973. (Report RSLR 73-3 for Naval Weapons Center, China Lake, Calif.)

[7] M. J. Pesko and R. H Stresau. *Development of the VARICOMP Method, Expansion of Applicability (To Determine Detonation Transfer Probabilities With Reduced Dependence Upon System Variables). Part 4. Preparation and Calibration of VARICOMP Mixtures With Minimum Dependence of Sensitivity Upon Donor Diameter.* Spooner, Wis., R. Stresau Laboratory, Inc., 21 January 1974. (Report RSLR 74-2 for Naval Weapons Center, China Lake, Calif.)

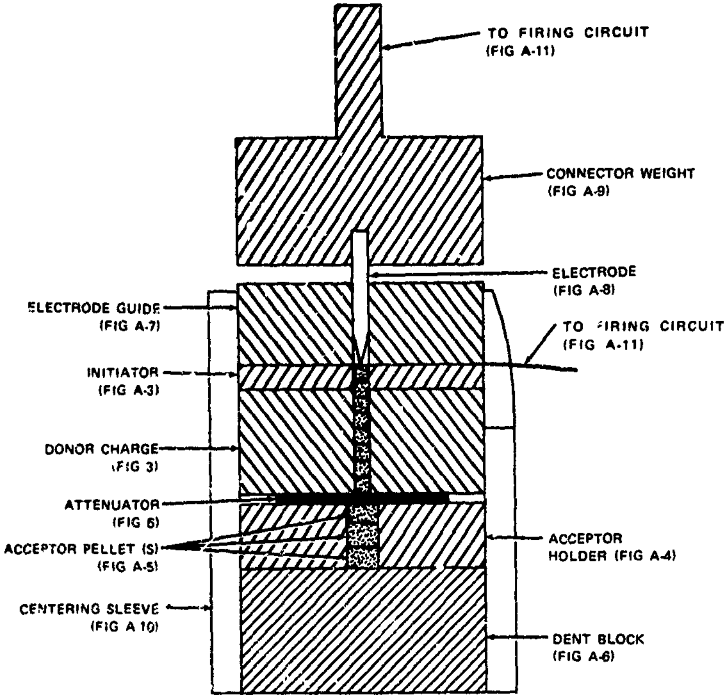


FIGURE 1. Proportional (Variable Donor Diameter) Gap Test.

1-mil foil, requires more than 1 ampere (or, in a pulse, about 100,000 ergs) to fire. The connector weight shown in Figure 1 also provides the contact force necessary for reliable initiation. In these studies the firing energy was provided by the discharge of a 1,600-microfarad capacitor charged to 90 volts (which is many times the energy required for initiation).

Donor Output and Charge

Donor dent output data with the arrangement shown in Figure 2 and the loading sequence and conditions of Figure 3 are given in Table 1.

The PBXN-5 used in the donor charge was Lot HOL 950-3 prepared by Holston Ordnance Works. It has a smaller grain size (approximately 16.5 to 33.1 mils) than normal PBXN-5, which has some grains almost as large as the largest (200-mil-diameter) donor used in these tests.

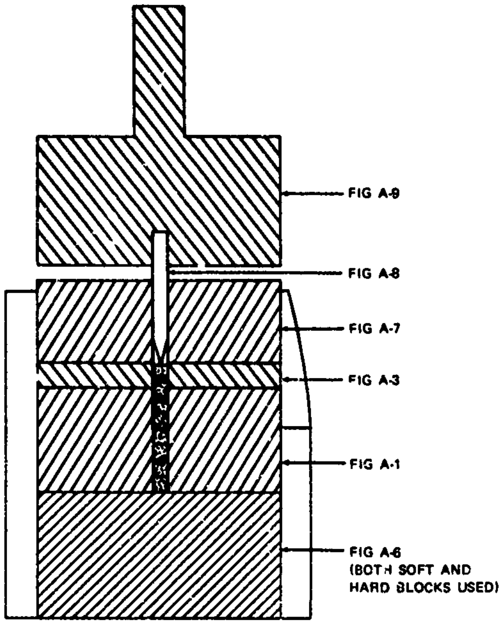


FIGURE 2. Donor Output Test.

Donor Pellets

The Stokes tablet machine was used to press the pellets because several thousand donor pellets of each size were required. Since the Stokes machine measures the charge volumetrically and presses it to constant dimensions, there was some question regarding the uniformity of density that could be attained. Because initial pellets pressed showed that the density varied much more than could be tolerated, the PBXN-5 was subdivided into three lots (1) that held on the 30-mesh sieve, (2) that which passed through a 30- but not a 35-mesh sieve, and (3) that which passed through the 35-mesh sieve; each of these was then used for each of the three pellet sizes To obtain uniform density, the Stokes press was modified with a elastomer die spring (Figure 4) to press to a nearly constant pressure, rather than a constant volume as it does in normal operation. With this modification the pellets were pressed as specified in Figure 5.

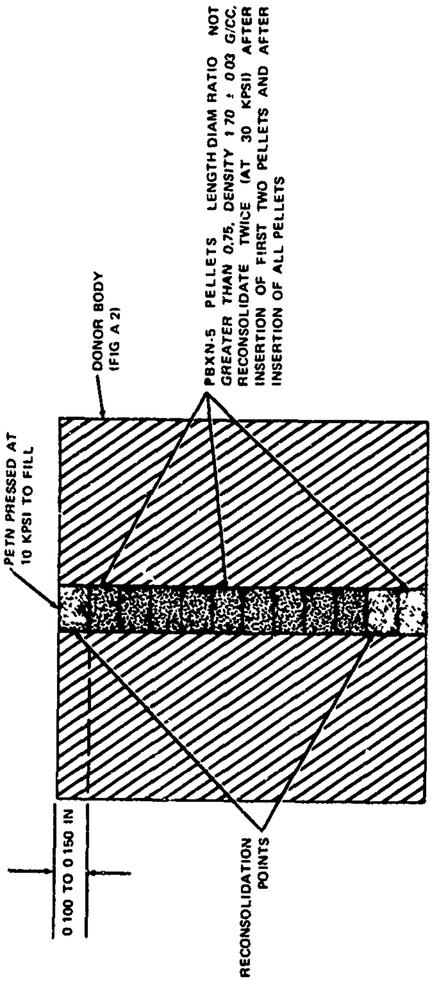


FIGURE 3. Donor Charge.

TABLE 1. Donor Dent Output Data.

Dent depth, mils

Donor charge diameter mils	Soft witness blocks Rockwell B (85-95)		Hardened witness blocks Rockv [illegible] 49-52)	
	Av	Std dev	Av	Std. dev
50	5 74	0 46	2 74	0 27
100	13 9	0 44	6 45	0.31
200	29 65	1 66	13 03	0 43

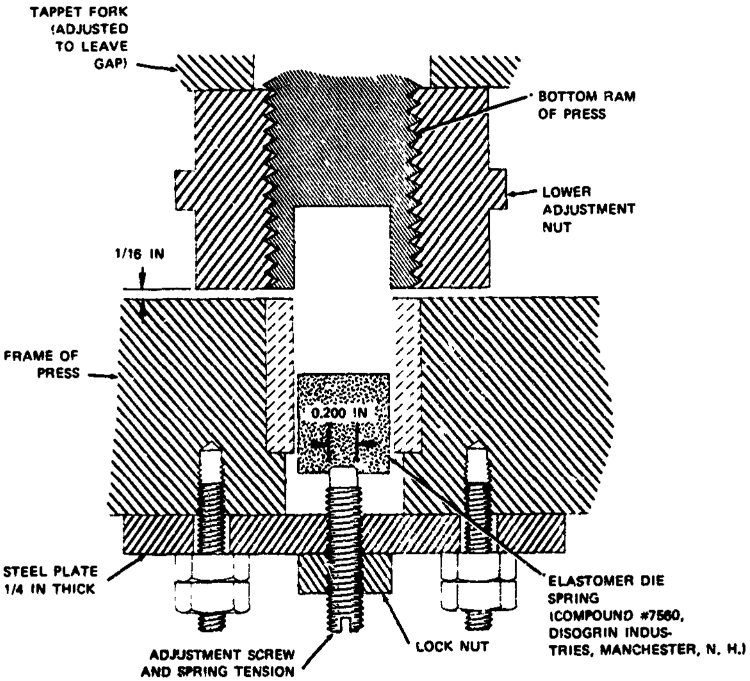
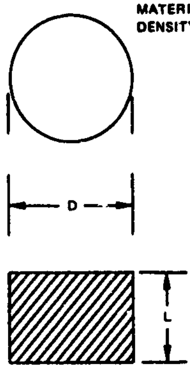


FIGURE 4. Modification of Stokes Tablet Machine (Model 11-4) for Constant Pressure Loading.

MATERIAL. PBXN-5, HOL LOT 950-3
DENSITY 1.70 ± 0.03 G/CC



ITEM	DIAMETER (D), IN	LENGTH (L), IN
1	$0.049 \begin{smallmatrix} +0.000 \\ -0.002 \end{smallmatrix}$	0.032 (REF)
2	$0.099 \begin{smallmatrix} +0.000 \\ -0.002 \end{smallmatrix}$	0.072 (REF)
3	$0.199 \begin{smallmatrix} +0.000 \\ -0.003 \end{smallmatrix}$	0.145 (REF)

FIGURE 5. Donor Pellet.

Acceptor Pellets

The acceptor pellets were hand-loaded at a constant pressure for each test, the explosive for each pellet being weighed separately. The loading pressure was adjusted to obtain the specified density after which the density was held constant for all the pellets used in a given test. Loading densities were determined from dimensions and weights of the individual pellets. Dimensions were usually measured with a micrometer or dial indicator height gauge, but for smaller pellets of softer materials, optical measurements were sometimes necessary (a pellet is compared with a drill blank of similar diameter in a photomicrograph). The pellets were weighed with an analytical or semimicro analytical balance.

Attenuators

The material used for the aluminum attenuators was 2011-0 aluminum for the thick ones and 1100-0 aluminum for the thin ones. Cold-rolled AISI C1215 steel was used in all cases for steel attenuators with 200-mil-diameter donors, and low carbon shim steel was used for 50- and 100-mil-diameter donors. Figure 6 gives details on the attenuators used and the alternate attenuators.

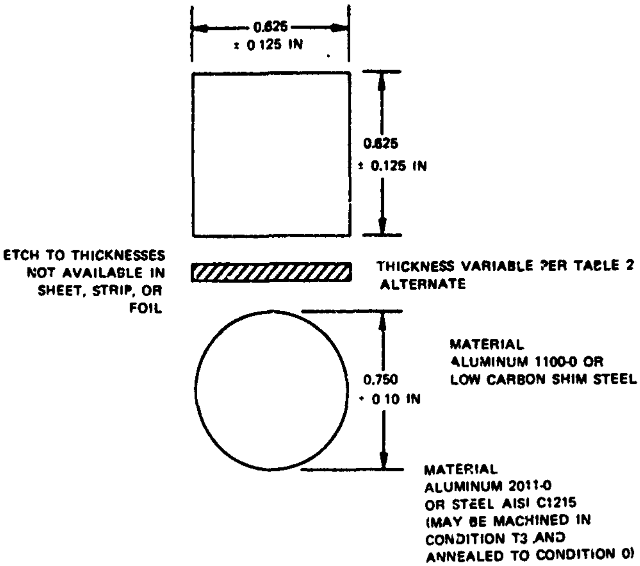


FIGURE 6. Attenuator.

Acceptor and Donor Holders

Delrin (trade name for an acetal resin thermoplastic) was used as the acceptor and donor holder material in all calibration tests It was chosen because, in general, it is a good impedance match for the explosive being calibrated and thereby minimizes reflected shock waves. In addition, the diameter of the acceptor was twice the diameter of the donor, which makes the acceptor appear infinite.

STATISTICAL ANALYSIS

The test procedure used in all explosive and VARICOMP calibrations was the Bruceton method for which the succession of "step size" should be uniform with respect to an appropriate "normalizing function." This resulted in the establishment of the so-called "decibang" (DBg) as a unit of initiation intensity (stimulus), DBg scale was used in the calibrations reported herein. The first trial of a test is performed at one of a series of preestablished sets of conditions or steps. The step size used in all calibrations was 0.25 DBg, except for 50-mil-diameter PBXN-5, Type II, with aluminum attenuators where the step size was 0.50 DBg. If a detonation results, the next test is performed at an adjacent step in the direction less conducive to detonation. If it misfires, the next test is performed at the adjacent step in the direction of increasing detonation transfer probability. The test is continued in this manner, the condition of each test being determined by the results of the previous ones until 30 tests in all are performed.

For each explosive (loaded at each pressure at which it is to be tested), two trials are performed with the arrangement shown in Figure 1, except that no attenuator is used. The depth of the dent produced in these two trials is averaged, and the "criterion of fire" used for this combination of explosive and loading pressure is taken as 50% of this average (the "zero gap dent").

The data obtained in the Bruceton test is then analyzed to obtain estimates of the mean (the condition at which 50% will detonate) and standard deviation of the test variable and the errors of these estimates. For the tests and calibrations reported herein, the probability of detonation is assumed to be a normal distribution, however, in Appendix B the data has been analyzed assuming a logistic distribution[8] that has been shown to more nearly approximate the actual distribution for electroexplosive devices and in general gives more conservative estimates of the "no-fire" and "all-fire" levels. No data is available as to whether the same is true for detonation transfer as reported herein. However, if the required reliability and safety can be established using the logistic analysis, there is greater assurance that the required levels have indeed been met, than with an assumed normal distribution.

Definition of Decibang (Small-Scale Gap Test)

The original VARICOMP procedure used DBg as its unit of stimulus to quantify sensitivity to initiation of various explosives. The SSGT was used for all calibrations of sensitivity. These tests used Lucite barrier (attenuator) material and provided a measure of shock transfer sensitivity only at a single diameter.

In the SSGT, the equation relating stimulus to barrier thickness is given as

$$X = 30 - 10 \log g$$

where

g is in mils and X is the stimulus in DBg, or

$$X = 10 \log \frac{1}{g}$$

where

g is the barrier thickness in inches.

[8] Naval Ordnance Laboratory. *Logistic Analysis of Bruceton Data*, by L. D. Hampton, G. D. Blum, and J. N. Ayres. White Oak, Md., NOL, 23 July 1973. (Report NOLTR 73-91.)

Definition of Proportional Gap Test

The new VARICOMP procedure used the PGT, and the proportional DBg is used as a unit of stimulus For the PGT reported herein, the same series of gap thickness was adopted, but to avoid ambiguities resulting from the detailed differences in test conditions from the SSGT, the sensitivity gap decibang unit is called relative decibang (RDBg) The calibration tests were performed using the same thickness barriers as the SSGT. Table 2 lists the DBg or RDBg values versus the thickness of the barriers

For the calibrations reported herein, the equation relating stimulus intensity in proportional DBg to system dimensions is

$$X \text{ (PAlDBg or DStDBg)} = 10 + 10 \log d/g$$

where d is the donor diameter in mils and g is the barrier thickness in mils. It was decided to identify the stimulus intensity as Proportional Aluminum Gap Decibang (PAlDBg) or Proportional Steel Gap Decibang (PStDBg), which also indicates attenuator material.

Calculation of Reliability Estimates

To convert from RDBg to PAlDBg or PStDBg, proceed as follows. For 100-mil-diameter donors, DBg or RDBg is equal to PAlDBg or PStDBg, since 10 log $1/g$ equals 10 + 10 d/g where d = 100 mils–Substituting d = 50 and 200 mils and subtract 3 01 DBg to convert to PAlDBg or PStDBg for the 50-mil-diameter donor and add 3 01 DBg for the 200-mil-diameter donor.

To obtain estimates of minimum values at 95% confidence of the stimulus level required for 99, 99.9, and 99 99% reliability, the maximum value at 95% confidence of the mean stimulus was added to 2 327, 3.090, and 3.719, respectively, times the maximum value at 95% confidence of the standard deviation.

To obtain required stimulus for any given value of reliability, assuming a normal distribution, the equation is as follows

$$X_t = X + T[\sigma_X + t(\sigma + T\sigma_\sigma)]$$

where

X_t = stimulus at desired reliability
T = 1 76
σ_X = standard deviation of mean
σ_σ = standard deviation of standard deviation
t = number of standard deviations from the mean for desired reliability
X = mean sensitivity
σ = standard deviation

The values of σ, σ_X, σ_σ, and X are taken from the tables for each of the design and VARICOMP explosives in this report. This is done for each of the three calibration diameters, and then a smooth curve is drawn through the three points to obtain the stimulus versus donor diameter curve.

TABLE 2. Gap Decibangs or Relative Decibangs as a Function of Barrier Thickness. (See Figure 6)

Decibang value	Nominal thickness, mils	Decibang value	Nominal thickness, mils
5.00	316.2	16.25	23.71
5.25	298.5	16.50	22.39
5.50	281.8	16.75	21.14
5.75	266.1	17.00	19.95
6.00	251.2	17.25	18.84
6.25	237.1	17.50	17.78
6.50	223.9	17.75	16.79
6.75	211.4	18.00	15.85
7.00	199.5	18.25	14.96
7.25	188.4	18.50	14.13
7.50	177.8	18.75	13.34
7.75	167.9	19.00	12.59
8.00	158.5	19.25	11.89
8.25	149.6	19.50	11.22
8.50	141.3	19.75	10.62
8.75	133.4	20.00	10.00
9.00	125.9	20.25	9.44
9.25	118.9	20.50	8.91
9.50	112.2	20.75	8.41
9.75	106.2	21.00	7.94
10.00	100.0	21.25	7.50
10.25	94.41	21.50	7.08
10.50	89.13	21.75	6.68
10.75	84.14	22.00	6.31
11.00	79.43	22.25	5.96
11.25	74.99	22.50	5.62
11.50	70.79	22.75	5.31
11.75	66.83	23.00	5.01
12.00	63.10	23.25	4.73
12.25	59.57	23.50	4.47
12.50	56.23	23.75	4.22
12.75	53.09	24.00	3.98
13.00	50.12		
13.25	47.32		
13.50	44.67		
13.75	42.17		
14.00	39.81		
14.25	37.58		
14.50	35.48		
14.75	33.50		
15.00	31.62		
15.25	29.85		
15.50	28.18		
15.75	26.61		
16.00	25.12		

CALIBRATION RESULTS

The results of all VARICOMP and design explosives calibrated are presented in both tabular and graphical form Reported are (1) RDX/calcium stearate binary series (the same as used in the original VARICOMP work done by NOL, White Oak, about 1960), (2) RDX/calcium soap series (developed during the effort reported herein), (3) CH-6, (4) PBXN-5, Type I, (5) PBXN-5, Type II (6) HNS-IA, and (7) PETN As mentioned previously, all calibrations were based on the 30-shot Bruceton test and statistically analyzed as a normal and logistic distribution

1. RDX/Calcium Stearate Binary Series (VARICOMP)

RDX/calcium stearate was chosen to be calibrated because it has a marked dependency of sensitivity in terms of peak pressure or gap units upon pulse duration or donor diameter. All acceptor pellets (RDX/calcium stearate) were pressed at 32 kpsi for the calibration tests After some preliminary tests with the series containing 4 99% calcium stearate (X358) and 9 16% calcium stearate (X366), where the X designation refers to the NOL, White Oak, lot identification of the various mixtures, it was felt that sensitivity spacing resulting from a change in stearate content by a factor of two seemed to be appropriate The following series with percentage content of stearate was chosen

X353, 2 54%
X358, 4 99%
X366, 9 16%
X384, 18.7%

It was found that 100-mil-diameter donors were incapable of initiating the material containing 18 7% calcium stearate (X384), 16 55% (X381), or 14 16% (X378) without any attenuator between the donor and acceptor. Therefore, it was decided to calibrate 12.79% (X374) as well as X353, X358, and X366 Tables 3 and 4 show the results of the calibration and Figure 7 and 8 are the graphical results of the mean sensitivity at the lower 95% confidence level, which will be useful for evaluation of an explosive train

2. RDX (2-Micron)/Calcium Soap Series (VARICOMP)

RDX (2-micron) calcium soap was chosen as one of the VARICOMP mixes whose sensitivity in terms of peak pressure or gap units would be relatively independent of pulse duration or donor diameter The lots have been designated 135A, 135B, and 135E. Many different explosive-desensitizer combinations were explored, and some of this effort and the details on the mixing of these VARICOMP lots are discussed in Appendix C.

TABLE 3 Proportional Gap Test Data for RDX/Calcium Stearate Binary Series Loaded at 32 kpsi With Aluminum Attenuators.

Acceptor material, stearate content, %/NOL No	Donor diameter, mils	Attenuator material	Acceptor density, g/cc	Mean sensitivity X, RDBg	Mean sensitivity X, PAIDBg	Std dev. σ, DBgg	Std dev of mean σ_X, DBg	Std. dev of std. dev σ_σ, DBg	Stimulus for 50%,[a] PAIDBg
2 54/X353	50	Al 1100-O[b]	1,671	18 392	15 382	0 633	0 152	0 312	15 115
	100	Al 2011-O[c]	1 669	11 342	11 242	0 163	0 045	0 054	11 162
	200	Al 2011 O[c]	1 660	6 825	9 735	0 245	0 064	0 087	9 623
4.99/X358	50	Al 1100-O[b]	1 614	21 413	18 403	0 625	0 161	0 333	18 117
	100	Al 2011 O[c]	1 638	11 692	11 592	0 163	0 044	0 053	11.514
	200	Al 2011-O[c]	1 627	7 214	10 124	0 085	0 028	0 061	10 070
9 16/X366	50			inf[d]				-	
	100	Al 1100-O[b]	1 607	14 125	14 125	0 188	0 051	0 062	14 034
	200	Al 2011-O[c]	1 609	8 00	10 91	0 063	0 021		10 872
12.79/X374	50			inf.[d]				.	
	100	Al 1100-O[b]	1 549	16.433	16 433	0 40	0 106	0.178	16 245
	200	Al 2011-O[c]	1 578	8 525	11 435	0 16	0 044	0 051	11 358

[a] Minimum at 95% confidence
[b] Sheet, strip, or foil
[c] Bar stock, sliced in lathe
[d] Infinity, acceptor was not initiated without an attenuator
[e] Standard deviation too small for deviation of deviation to be calculated by Bruceton analysis procedure

TABLE 4. Proportional Gap Test Data for RDX/Calcium Stearate Binary Series Loaded at 32 kpsi With Steel Attenuators.

Acceptor material, stearate content, %/NOL No	Donor diameter, mils	Attenuator material	Acceptor density, g/cc	Mean sensitivity X, RDBg	Mean sensitivity X,[a] PStDBg	Std dev. σ, DBg	Std dev of mean σ_X, DBg	Std. dev. of std dev. σ_σ DBg	Stimulus for 50%,[a] PStDBg
2 54/X353	50	Steel[b]	1 671	23 742	20 732	0 60	0 144	0.291	20,478
	100	Steel[b]	1 669	15.358	15 358	0 25	0 065	0 089	15 244
	200	Steel, C1215[c]	1 660	10.542	13 526	0 155	0 043	0.051	13 449
4 99/X358	50	Steel[b]	1.614	25 292	22 282	0.268	0 069	0 097	22.161
	100	Steel[b]	1 638	15 992	15 992	0 063	0 021	[d]	15.955
	200	Steel, C1215[c]	1 627	10 696	13 680	0 095	0 031	0 052	13 625
9 16/X366	50	Steel[b]		inf.[c]		.	-	.	.
	100	Steel[b]	1 607	20 304	20 304	0 443	0.199	0 195	20 105
	200	Steel, C1215[c]	1 609	11.867	14.857	0.093	0 031	0 042	14 803
12.79/X374	50	Steel[b]	.	inf[c]		-		-	
	100	Steel[b]	1 549	22 357	22 357	0 443	0 112	0 195	22 158
	200	Steel, C1215[c]	1 578	12 758	15 742	0 275	0 068	0 101	15 622

[a] Minimum at 95% confidence
[b] Low carbon shim steel
[c] Bar stock, sliced in lathe
[d] Standard deviation too small for deviation of deviation to be calculated by Bruceton analysis procedure
[c] Infinity, acceptor was not initiated without an attenuator

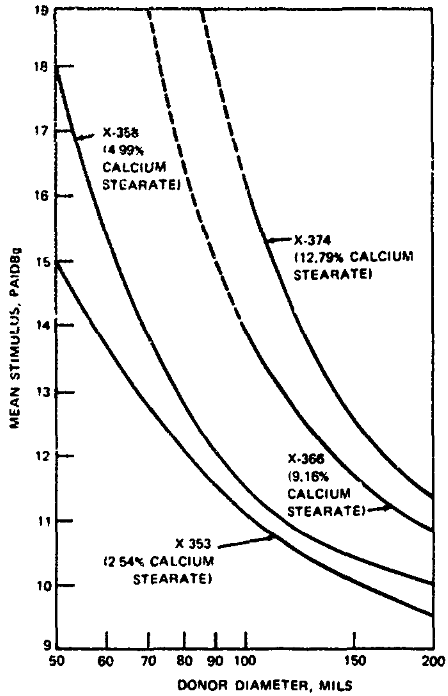


FIGURE 7. Proportional Gap Sensitivities (Minimum at 95% Confidence) of RDX/Calcium Stearate Binary Series With Aluminum Attenuators. Binary series described in NOLTR 63-91 (see text footnote 9)

For the calibration of this VARICOMP mix, the explosive was prepelleted at a pressure of 100 kpsi. Densities were determined by dividing the weights of the pellets by their volumes. Densities so measured are average densities, giving no clue regarding point-to-point variations in local density. It is reasonable to expect that the local density at the input surface would affect the sensitivity to initiation more directly than the average density. This was verified by a short test of material from Lot 135E using 100-mil-diameter donors and steel attenuators in which sensitivities of the two ends of a pellet were compared. With the "hard" end (that toward the moving ram in the pressing operation) toward the donor, the mean stimulus was 20.375 PStDBg, while the "soft" end toward the donor, the mean stimulus was 18.54 PStDBg.

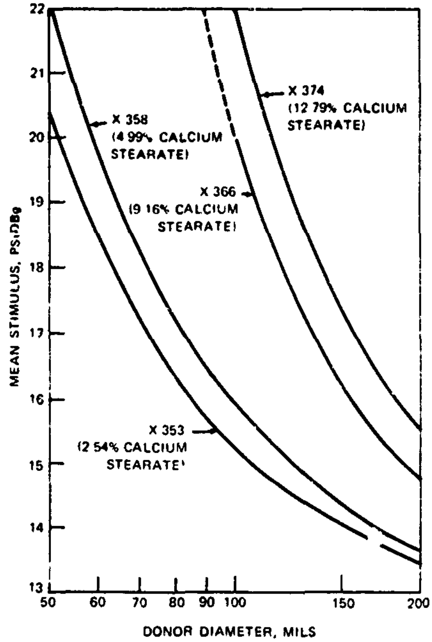


FIGURE 8 Proportional Gap Sensitivities (Minimum at 95% Confidence) of RDX/Calcium Stearate Binary Series With Steel Attenuators. Binary series described in NOLTR 63-91 (see text footnote 9)

A study of the data reveals further evidence that density gradients in pellets pressed in single action pelleting tools can significantly affect gap test results [9] In addition to the effects of this gradient, the pellet density may differ from local density because of cracks that are often apparent along planes perpendicular to the axes of the pellets Sometimes these cracks may cause enough axial expansion to reduce the calculated density significantly Another source of density variation was the expansion of the pellets with time When Lot 135E was first made, a few sample pellets (400 mils in diameter) were pressed and the density determined within a few minutes, the density at this time was between 98 and 99% of the maximum theoretical density. However, a sample drawn from these pellets after a few days had a density of only 97.2% of the maximum theoretical density. The effect of this relaxation on gap tests results was noted where the mean stimulus in the screening tests (those performed shortly after the mix was completed) was higher with the 200-mil-diameter donors and lower with the 50-mil-diameter donors than was the mean stimulus of the Bruceton tests.

[9] Naval Ordnance Laboratory *RDX/Calcium Stearate Binary System Explosive Sensitivity Calibration*, by J. N Ayres and C W RAndall White Oak, Md, NOL, 15 May 1970. (Report NOLTR 63-91)

The foregoing discussion of density effects suggests that, when using material from Lots 135A, 135B, and 135F as VARICOMP surrogates (with the calibration data given herein), the specimens be prepared as follows

1 Prepellet whenever possible

2 Use headless press-fit drill bushings as dies and drill blanks of the same size designation as rams, bushings and blanks are each made by a number of manufacturers to standard fractional letters and number drill sizes Figure 9 shows the general design of the leading tools

3 Press at 100,000 pounds per square inch with a 10-second dwell.

4 Allow pellets to age 24 to 48 hours before testing.

5 Determine loading density of pellets They should be close to those values listed in Tables 5 and 6

6 Install with "hard" end (that toward moving ram when pressing) toward the donor

Tables 5 and 6 show the results of the calibration and Figures 10 and 11 are the graphical results of the mean sensitivity at the lower 95% confidence level, which will be useful for evaluation of an explosive train

Data reported herein led to the conclusions that

1 RDX can be reduced, in particle size, (2 microns maximum) by solution in hot acetone and precipitation by mixing, in a turbulent flow, with ice water (see Appendix C)

2 Such finely divided RDX, coated with calcium soap (precipitated from sodium soap solutions in which the RDX is suspended as a slurry) and pressed at 100,000 psi, to densities over 95% of the theoretical maximum of the mixture, has sensitivities appreciably less dependent upon donor size (in proportional gap tests) than coarser (Class A) RDX coated with calcium stearate

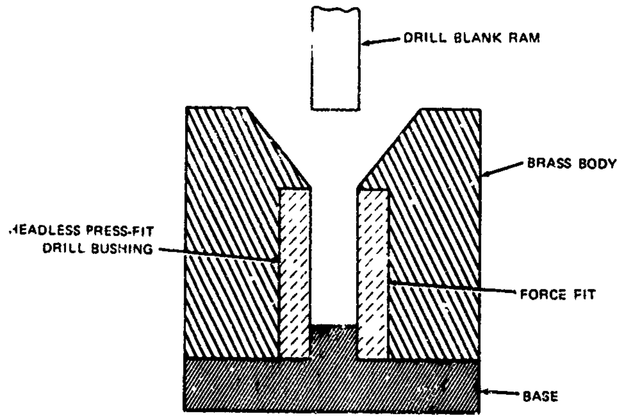


FIGURE 9. Suggested Pellet Loading Tool Design.

TABLE 5. Proportional Gap Test for RDX/Calcium Soap Series Loaded at 100 kpsi With Aluminum Attenuators.

Acceptor material, soap content, %/lot no.	Donor diameter, mils	Attenuator material	Acceptor density, g/cc	Max theoretical density, %	Mean sensitivity X, RDBg	Mean sensitivity X, PAIDBg	Std dev σ, DBg	Std dev of mean $\sigma_{\bar{X}}$, DBg	Std dev of std dev σ_σ DBg	Stimulus for 50%[a] PAIDBg
11 589/135A	50	Al 1100-0[b]	1 5946[c]	95 5	19 0536	16 0436	0 6625	0 1682	0 3506	15 7158
	100	Al 2011 0[d]	1 589	95 2	12 2404	12 1404	0 775	0 1982	0 4514	11 7876
	200	Al 2011 0[d]	1 606	96 2	8 1428	11 0528	0 50	0 1256	0 2338	10 8305
5 5041/135B	50	Al 1100-0[b]	1 6639[c]	95 6	17 7679	14 6679	0 1625	0 0473	0 0551	14 5841
	100	Al 2011-0[d]	1 656	95 1	12 7181	12 6181	0 1915	0 0770	0 1134	12 4818
	200	Al 2011-0[d]	1 645	94 5	7 875	10 785	0 0875	0 0323	0 0235	10 7279
19 523/135E	50	Al 1100-0[b]	1 5540[c]	98 19	22 5625	19 5525	0 620	0 1527	0 2279	19 2845
	100	Al 2011-0[d]	1 5381	97 16	13 1083	13 0083	0 6425	0 1538	0 4878	12 7376
	200	Al 2011-0[d]	1 5370	97 09	8 3583	11 2683	0 1375	0 0458	0 0399	11 1877
22 256/135D	50	Al 1100-0[b]			inf[e]					
	100	Al 2011-0[d]	1 510	97 2	13 9750	13 8750	0 33	0 0829	0 1268	13 7291
	200	Al 2011-0[d]	.		8 1750	11 0850	0 1875	0 0508	0 0634	10 9956

[a] Minimum at 95% confidence

[b] Sheet, strip, or foil.

[c] Use of micrometer and analytical balance for these small measurements and weights are questionable for accurate density determination

[d] Bar stock, sliced in lathe

[e] Infinity, acceptor was not initiated without an attenuator

TABLE 6 Proportional Gap Test Data for RDX/Calcium Soap Series Loaded at 100 kpsi With Steel Attenuators

Acceptor material, soap content, %/lot no.	Donor diameter, mils	Attenuator material	Acceptor density, g/cc	Max theoretical density, %	Mean sensitivity X, RDBg	Mean sensitivity X PSt DBg	Std Dev σ, DBg	Std dev. of mean σ_X, DBg	Std dev of std dev σ_σ, DBg	Stimulus for 50%,[a] PSt DBg
11.589/135A	50	Steel[b]	1.5946[c]	95.5	24.3417	21.3317	0.4000	0.0967	0.1662	21.1579
	100	Steel[b]	1.589	95.2	16.35715	16.35715	0.5625	0.2673	0.5235	16.3500
	200	Steel, C1215[d]	1.606	96.2	12.0917	15.1017	0.1200	0.0474	0.0557	15.0183
5.5941/135B	50	Steel[b]	1.6639[c]	95.6	22.8417	19.8317	0.1700	0.0474	0.0557	19.7483
	100	Steel[b]	1.656	95.1	16.7500	16.7500	0.3425	0.0885	0.1409	16.5933
	200	Steel, C1215[d]	1.645	94.5	11.5583	14.5683	0.1625	0.0457	0.0532	14.4878
19.5230/135E	50	Steel[b]	1.5540[c]	98.19	26.3583	23.3483	0.2575	0.0665	0.0924	23.2313
	100	Steel[b]	1.5381	97.16	18.5417	18.5417	0.3175	0.0799	0.1188	18.4010
	200	Steel, C1215[d]	1.5370	97.09	12.1964	15.2064	0.3250	0.0846	0.1294	15.0567
22.2[illegible]6/135D	50	Steel[b]		.	inf.[e]	. .	.	.		.
	100	Steel[b]	1.510	97.2	19.7679	19.7679	0.3400	0.0879	0.1391	19.6124
	200	Steel, C1215[d]	. .		12.0583	15.0683	0.0925	0.0311	0.0356	15.0136

[a] Minimum at 95% confidence

[b] Low carbon shim steel.

[c] Use of micrometer and analytical balance for these small measurements and weights are questionable for accurate density determination

[d] Bar stock, sliced in lathe.

[e] Infinity, acceptor was not initiated without an attenuator.

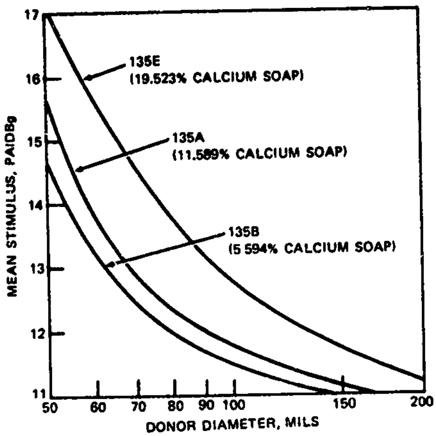


FIGURE 10. Proportional Gap Sensitivities (Minimum at 95% Confidence) of RDX (2-Micron)/Calcium Soap VARICOMP Surrogates With Aluminum Attenuators.

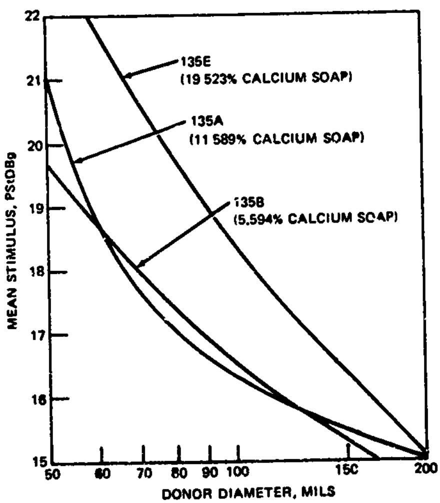


FIGURE 11. Proportional Gap Sensitivities (Minimum at 95% Confidence) of RDX (2-Micron)/Calcium Soap VARICOMP Surrogates With Steel Attenuators.

3. Calibration data have been obtained with the proportional gap test of three such mixtures containing 5 6 (135B), 11.6 (135A), and 19.5% (135E) calcium soap. These data can then be plotted in coordinates of proportional decibangs versus donor diameter along with similar data for members of the existing RDX, Class A/calcium stearate binary series of VARICOMP surrogates and printed on transparencies Finally, superposition of the VARICOMP on similar plots for design explosives can be used to rapidly design and interpret VARICOMP experiments to evaluate reliability of fuze explosive systems

4 It is recommended that, when using the 135 series mixtures as VARICOMP surrogates, specimen preparation simulate as closely as practical that used in calibration tests

3. CH-6

The CH-6 calibrated was from Holston Ordnance Works, Lot HOL-120-2, which is an average lot of CH-6. Figure 12 is a plot of the mean stimulus for initiation of CH-6 at densities of 1 6 and 1 7g/cc as determined with steel and aluminum attenuators. The most obvious feature of Figure 12 is the proximity of the curves for the two densities at the larger donor diameter and the wide separation at the smaller donor diameter This separation by density indicates that the critical diameter of CH-6 is smaller at a density of 1.7 g/cc than at a density of 1 6 g/cc From the practical viewpoint, Figure 12 serves to emphasize the need, where donors of small sizes are used, for the specification and maintenance of relatively high loading densities for CH-6 acceptors. Figures 13 through 16 are additional plots of CH-6 and one of the VARICOMP series for various densities and attenuators Table 7 lists the calibration data results for CH-6

4. PBXN-5, Type I

Results of the PGT for an assumed normal distribution of PBXN-5, Type I, at densities of 1 7 and 1 8 g/cc are given in Table 8 and plotted in Figures 17 through 21 Note the significantly lower variability with respect to size as compared to CH-6

5. PBXN-5, Type II

The PBXN-5, Type II, was calibrated using only aluminum attenuators at densities of 1 7 and 1 8 g/cc and was identified as "Bimodal PBXN-5, Batch 5103-L-1, Lot 578-1." The "bimodal" designation indicates that it is made prior to the issuance of a current specification for PBXN-5 in which the designation "Type II" was applied to the bimodal material.

Results are given in Table 9 and plotted in Figures 22 and 23. In Figure 24, the mean stimulus for initiation of PBXN-5, Type II, is compared with similar data for PBXN-5, Type I, and CH-6. It may be noted that the curves for PBXN-5, Type II, are much closer to those for CH-6 than to PBXN-5, Type I. This tends to corroborate earlier impressions that state of aggregation, and in particular particle size and distribution, can outweigh composition in affecting suceptibility to initiation In this respect, it has long been known that diameter effects can be more severe and failure-diameters can be larger in a bimodal mixture than when either the coarse or fine component of the mixture is used

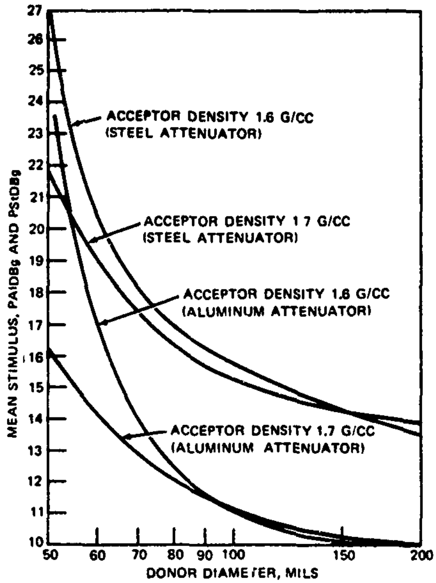


FIGURE 12. Proportional Gap Test Data (Minimum at 95% Confidence) for CH-6

At the lower density (1 7 g/cc), none of the VARICOMP explosives that have been calibrated can be used in reasonable sample sizes to demonstrate reliability. Therefore, it is recommended that:

1 The use of PBXN-5, Type II, be avoided in fuze explosive components that must be initiated by small sources or attenuated stimuli

2. In any fuze component application, PBXN-5, Type II, should be loaded at a minimum density of 1 8 g/cc

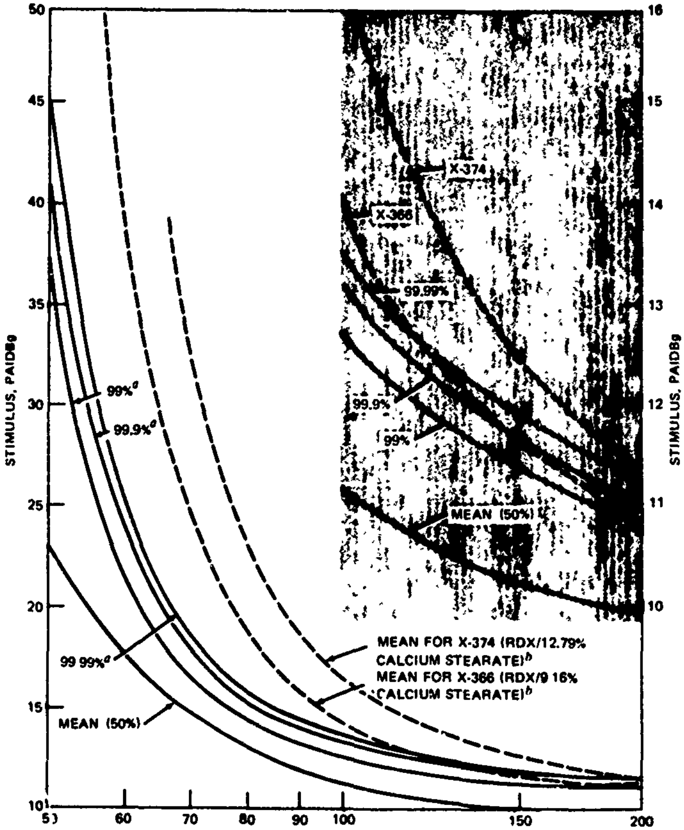
3. Any system in which PBXN-5, Type II, is to be used should function consistently (better than 50% at 95% confidence) with the VARICOMP X374 (containing 12.79% calcium stearate) substituted for the PBXN-5, Type II.

6. HNS-IA

The HNS-IA calibrated was supplied by Chemtronics Inc. and identified as HNS-IA, Lot No. 64-7, Date of Manufacture 3-72. The two densities calibrated were 1.4 and 1.55 g/cc using only aluminum attenuators. The results of this calibration (Table 10 and Figures 25 and 26) indicate:

1. Density as tested (1.4 and 1.55 g/cc) has no appreciable effects on the initiation stimulus required for HNS-IA.

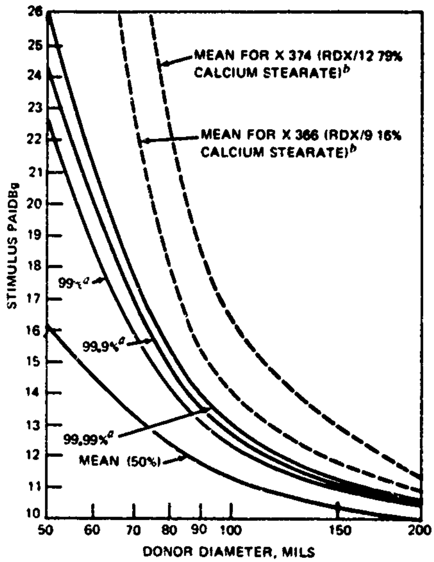
2. In any system in which HNS-IA is used, the best VARICOMP substitute would be 135E (19.23% desensitized RDX).



[a] MINIMUM RELIABILITIES AT 95% CONFIDENCE

[b] DATA FROM RSLR 73-1 (SEE TEXT FOOTNOTE 4) FOR MEMBERS OF BINARY SERIES DESCRIBED IN NOLTR 63-91 (SEE TEXT FOOTNOTE 9)

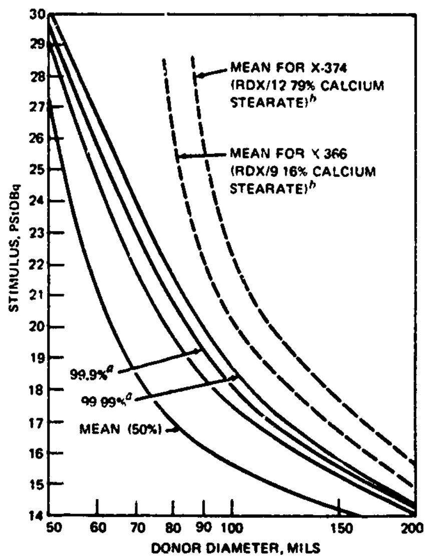
FIGURE 13. Proportional Gap Test Data for CH-6 at 1.6 g/cc and VARICOMP Surrogates, With Aluminum Attenuators.



[a] MINIMUM RELIABILITIES AT 95% CONFIDENCE

[b] DATA FROM RSLR 73-1 (SEE TEXT FOOTNOTE 4) FOR MEMBERS OF BINARY SERIES DESCRIBED IN NOLTR 63-91 (SEE TEXT FOOTNOTE 9)

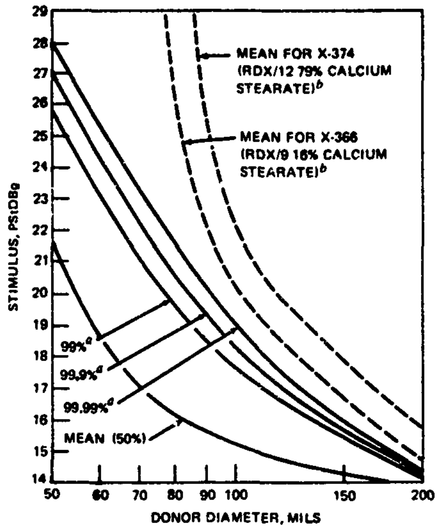
FIGURE 14. Proportional Gap Test Data for CH-6 at 1.7 g/cc and VARICOMP Surrogates, With Aluminum Attenuators.



[a] MINIMUM RELIABILITIES AT 95% CONFIDENCE

[b] DATA FROM RSLR 73-1 (SEE TEXT FOOTNOTE 4) FOR MEMBERS OF BINARY SERIES DESCRIBED IN NOLTR 63-91 (SEE TEXT FOOTNOTE 9)

FIGURE 15. Proportional Gap Test Data for CH-6 at 1.6 g/cc and VARICOMP Surrogates, With Steel Attenuators.



^{a} MINIMUM RELIABILITIES AT 95% CONFIDENCE

^{b} DATA FROM RSLR 73-1 (SEE TEXT FOOTNOTE 4) FOR MEMBERS OF BINARY SERIES DESCRIBED IN NOLTR 63-91 (SEE TEXT FOOTNOTE 9)

FIGURE 16. Proportional Gap Test Data for CH-6 at 1.7 g/cc and VARICOMP Surrogates; With Steel Attenuators.

7. PETN

PETN was calibrated for use in explosive train safety evaluation tests. Two different types of PETN were evaluated; one was PETN Superfine and the other was PETN from Burlington, Iowa, Lot D471. Preliminary tests of PETN Superfine revealed that it would not be sensitive enough for safety evaluation. Therefore, the other lot, which is the same type PETN used in the manufacture of PBXN-301, was used in the calibration tests. The density of the pellets used in the calibration was 1.4 g/cc. Table 11 shows the results of the calibration.

TABLE 7. Calibration Data for CH 6.

Donor diameter, mils	Attenuator material	Acceptor density, nominal g/cc	Acceptor density measured, g/cc	Mean sensitivity X, RDBg	Mean sensitivity X'[a] PAIDBg and PStDBg	Std dev σ, DBg	Std dev of mean σ_X, DBg	Std dev of std. dev σ_σ, DBg	Stimulus for 99%,[a b] PAIDBg and PStDBg	Stimulus for 99 9%,[b] PAIDBg and PStDBg	Stimulus for 99 99%,[b] PAIDBg and PStDBg
50	Al 1100-0[c]	1 6	1 5919	26 875	23 289	2 0425	0 548	2 155	38 119	42 653	46 457
100	Al 2011-0[d]	1 6	1 6115	11 232	11 119	0 345	0 089	0 141	12 686	13 114	13 405
200	Al 2011-0[d]	1 6	[illegible]	6 982	9 892	0 170	0 0486	0 0909	10 748	11 0005	11 2123
50	Al 1101-0[c]	1 7	1.6947	19 658	16 276	1 1825	0 2778	0 7633	22 642	24 569	26 185
100	Al 2011 0[d]	1 7	1 6889	11 32	11 233	0 258	0 0688	0 0950	12 345	12 668	12 942
200	Al 2011-0[d]	1.7	1 6915	6 992	9 903	0 0658	0 0216	0 0458	10 282	10 394	10 487
50	Steel[c]	1 6	1 5919	30 675	27 232	0 400	0 099	0 165	29 013	29 540	29.982
100	Steel[e]	1 6	1 6115	15 625	15 675	0 420	0 106	0 183	17 595	18 162	18 639
200	Steel, C1215[d]	1 6	1 601	10 542	13 554	0 09375	0 0315	0 0508	14 036	14 176	14 293
50	Steel[e]	1 7	1 6947	25 179	21 885	0 775	0 191	0 435	25 817	26 996	27 984
100	Steel[e]	1.7	1 6889	15 286	15 231	0 508	0 128	0 239	17 6.7	18 337	18 932
200	Steel, C1215[d]	1.7	1 6915	10 758	13 788	0 06575	0 0380	0 0307	14 167	14 279	14 372

[a] Corrected to nominal density
[b] Minimum at 95% confidence
[c] Sheet, strip, or foil.
[d] Bar stock, sliced in lathe
[e] Low carbon shim steel

TABLE 8 Proportional Gap Test Data for PBXN 5, Type I.

Donor diameter, mils	Attenuator material	Acceptor density, g/cc	Mean sensitivity X, RDBg	Mean sensitivity X,[a] PAIDBg and PStDBg	Std dev σ, DBg	Std dev of mean σ_X, DBg	Std dev of std dev σ_σ, DBg	Stimulus for 99%,[b] PAIDBg and PStDBg	Stimulus for 99.9%,[b] PAIDBg and PStDBg	Stimulus for 99.99%,[b] PAIDBg and PStDBg
50	Al 1100-0[c]	1.7	14 625	11 615	0 305	0 080	0 119	12 956	13 350	13.682
100	Al 1100-0[c]	1.7	10 5085	10 5085	0 1688	0 0465	0 0819	11 2146	11 4193	11 5924
200	Al 2011-0[d]	1 7	6.725	9 635[e]	0.1594	0 0446	0 0785	10 3051	10.4969	10 6591
50	Al 1100-0[c]	1.7844	14 8083	11 836	0 255	0 066	0 0915	12 920	13 238	13.506
100	Al 1100-0[c]	1.79	11.0085	11 085	0 330	0 0832	0.128	12 521	12.934	13 290
200	Al 2011-0[d]	1.80	7.175	10 085	0 180	0 0491	0 0595	10.834	11.051	11 235
50	Steel[f]	1 7	18.392	15 382	0 073	0 025	0 075	15 880	16 017	16 150
100	Steel[f]	1 7	13.992	13.992	0.169	0.047	0 055	14 692	14 895	15 066
200	Steel, C1215[d]	1.7	10.357	13.341[e]	0.155	0 045	0 051	13 994	14.182	14.339
50	Steel[f]	1.7844	19.339	16 514	0 290	0 076	0 112	17.184	18 156	18 470
100	Steel[f]	1 79	14 357	14.397	0 270	0 071	0 101	15 571	15.914	16.204
200	Steel, C1215[d]	1 80	10.725	13 709[e]	0 095	0 031	0 042	14.155	14 288	14 416

[a] Corrected to nominal density.
[b] Minimum at 95% confidence.
[c] Sheet, strip, or foil
[d] Bar stock, sliced in lathe
[e] Adjusted to equivalent for aluminum 1100 0 or low carbon shim steel
[f] Low carbon shim steel.

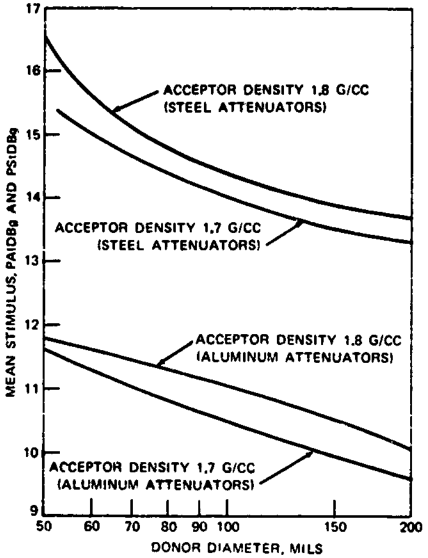
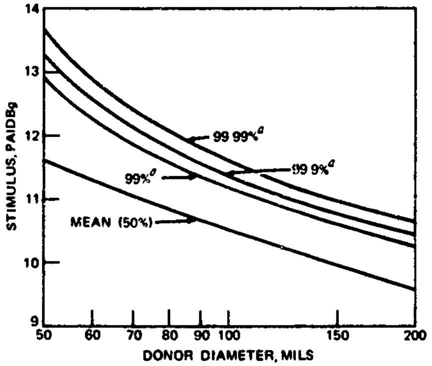
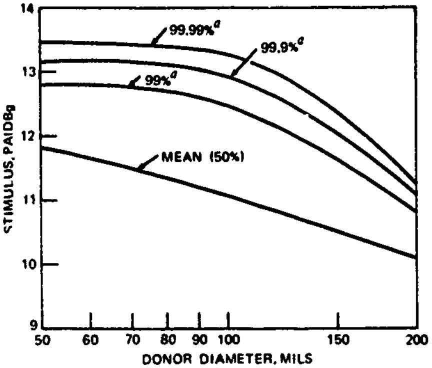


FIGURE 17. Proportional Gap Test Data (Minimum at 95% Confidence) for PBXN-5, Type I.



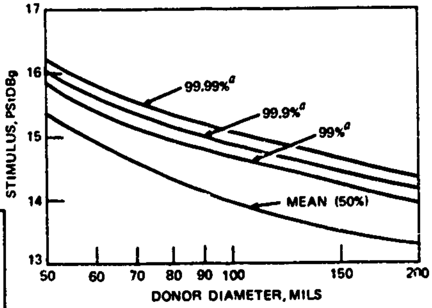
[a] MINIMUM RELIABILITIES AT 95% CONFIDENCE

FIGURE 18. Proportional Gap Test Data for PBXN-5, Type I, at 1.7 g/cc, With Aluminum Attenuators.



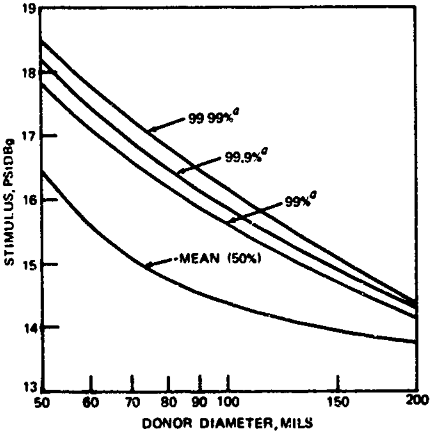
[a] MINIMUM RELIABILITIES AT 95% CONFIDENCE

FIGURE 19. Proportional Gap Test Data for PBXN-5, Type I, at 1.8 g/cc, With Aluminum Attenuators.



[a] MINIMUM RELIABILITIES AT 95% CONFIDENCE

FIGURE 20. Proportional Gap Test Data for PBXN-5, Type I, at 1.7 g/cc, With Steel Attenuators.



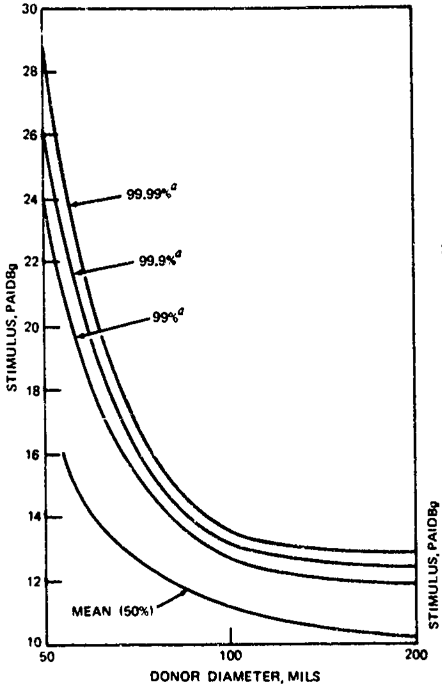
[a] MINIMUM RELIABILITIES AT 95% CONFIDENCE

FIGURE 21. Proportional Gap Test Data for PBXN-5, Type I, at 1.8 g/cc; With Steel Attenuators.

TABLE 9 Calibration Data for PBXN 5, Type II; Normal Distribution (Bruceton Data)

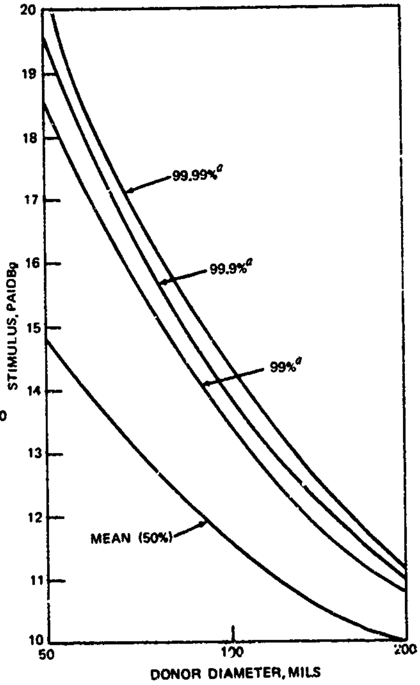
Donor diameter, mils	Attenuator material	Acceptor density, nominal, g/cc	Acceptor density, measured, g/cc	Mean sensitivity X, RDBg	Mean sensitivity X,[a] PAIDBg	std dev σ, DBg	Std dev of mean σ_X, DBg	Std dev of std dev σ_σ, DBg	Stimulus for 99%,[b] PAIDBg	Stimulus for 99 9%,[b] PAIDBg	Stimulus for 99 99%,[b] PAIDBg
50	Al 1100-0[c]	1 7	1 6995	18 7917	15 7817	1 70	0 4515	1 0453	24 0672	26 7839	29 0805
100	Al 2011 0[d]	1 7	1 6920	11 2679	11 1679	0 3375	0 0875	0 1362	12 6691	13 1107	13 4839
200	*Al 2011 0[d]*	*1 7*	*1 7020*	*7 375*	*10 285*	*0 4675*	*0 0946*	*0 1532*	*11 9387*	*12 4260*	12 8379
50	Al 1100-0[c]	1 8	1 7982	17 9038	14 8938	0 82	0 2170	0 3662	18 7049	19 8279	20 7772
100	Al 2011-0[d]	1 8	1 8023	11 6083	11 5083	0 415	0 1020	0 1736	13 3644	13 9141	14 3789
200	Al 2011 0[d]	1 8	1 7875	6 925	9 835	0 1875	0 0508	0 0629	10 6186	10 8464	11 0387

[a] Corrected to nominal denisty
[b] Minimum at 95% confidence
[c] Sheet, strip, or foil
[d] Bar stock, sliced in lathe



[a] MINIMUM RELIABILITIES AT 95% CONFIDENCE

FIGURE 22. Proportional Gap Test Data for PBXN-5, Type II, at 1.7 g/cc, With Aluminum Attenuators.



[a] MINIMUM RELIABILITIES AT 95% CONFIDENCE

FIGURE 23. Proportional Gap Test Data for PBXN-5, Type II, at 1.8 gcc, With Aluminum Attenuators.

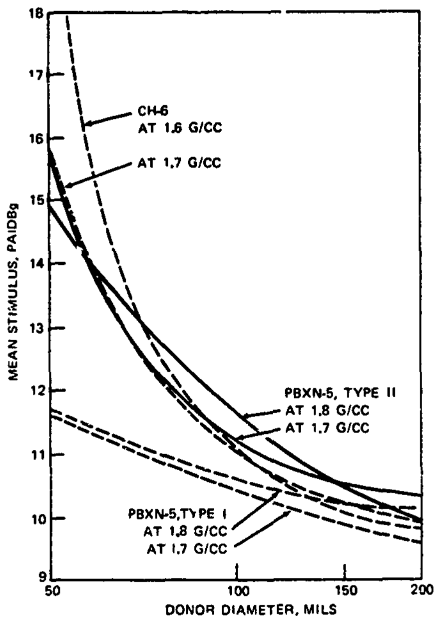


FIGURE 24. Proportional Gap Test Data for PBXN-5, Type II, Compared With PBXN-5, Type I, and CH-6, With Aluminum Attenuators.

USE OF DATA

In evaluating the reliability of an explosive train, the acceptor explosive is usually specified. The first step in evaluating the train is "matching of slopes." Curves for the design explosives and the appropriate attenuator medium are selected from the curves of stimulus versus diameter for the two VARICOMP series If combinations of steel and aluminum or other media are involved in the system under investigation, it is advisable to use both sets of data and believe the least optimistic. When transparencies of the curves of stimulus versus diameter for the two VARICOMP surrogates are used as overlays to the design explosive curve (with data for the same attenuating medium as the transparency), the slopes of the curves for the VARICOMP surrogates are compared with those for the design explosive The scales on the ordinate must be identical. If the slopes of the curves for the design explosive are similar to those of one or the other of the VARICOMP surrogates, that series can be used in the data collection scheme Once the VARICOMP series is selected, a number of identical tests of the system to be evaluated should be performed with the same VARICOMP surrogate substituted for that design explosive.

TABLE 10. Calibration Data for HNS-IA; Type II; Normal Distribution (Bruceton Data)

Donor diameter, mils	Attenuator material	Acceptor density, nominal, g/cc	Acceptor density, measured, g/cc	Mean sensitivity X, RDBg	Mean sensitivity X,[a] PAIDBg	std dev σ, DBg	Std. dev. of mean σ_X, DBg	Std dev of std dev σ_σ, DBg	Stimulus for 99%[b] PAIDBg	Stimulus for 99 9%,[b] PAIDBg	Stimulus for 99 99%,[b] PAIDBg
50	Al 1100-0[c]	1.40	1 3951	14.175	11 165	0 2375	0 0619	0.0834	12 1191	12 4116	12 5209
100	Al 2011-0[d]	1 40	1.4039	10 5583	10 5583	0 2125	0 0565	0 0730	11 4064	11 6660	11 8854
200	Al 2011-0[d]	1 40	1.3993	7 075	9 985	0 1375	0 0401	0 0462	10 5329	10 6592	10 8401
50	Al 1100-0[c]	1 55	1 5496	14 2417	11 2317	0 325	0 0816	0 1259	12 5822	12 9983	13 3500
100	Al 2011-0[d]	1.55	1 5448	10 3583	10 3583	0 1675	0 0467	0 0576	11 0291	11 2337	11 4067
200	Al 2011-0[d]	1 55	1 5490	7 0416	9 9500	0 15	0 0426	0 0484	10 5387	10.7178	10 8692

[a] Corrected to nominal density
[b] Minimum at 95% confidence
[c] Sheet, strip, or foil.
[d] Bar stock, sliced in lathe

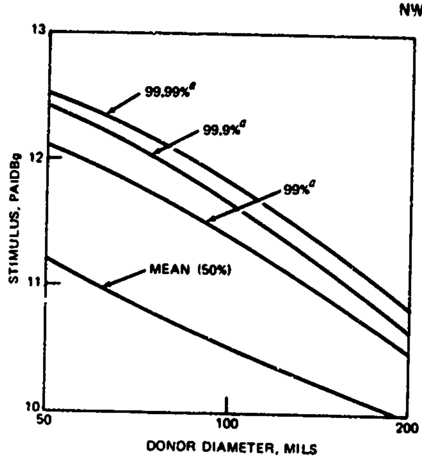


FIGURE 25. Proportional Gap Test Data for HNS-IA at 1.4 g/cc, With Aluminum Attenuators.

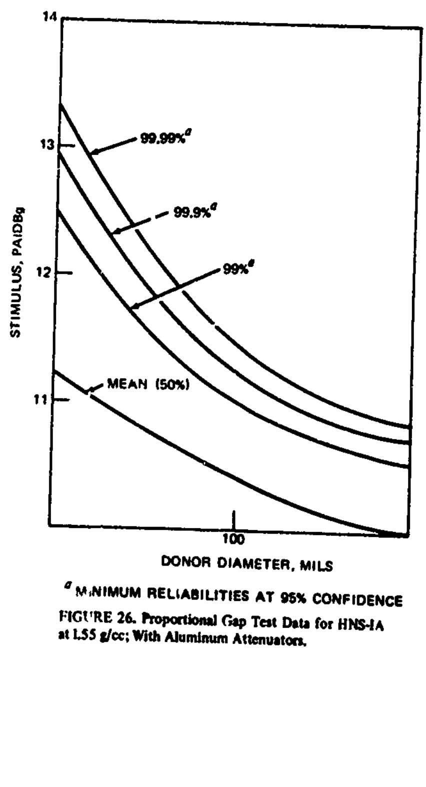


FIGURE 26. Proportional Gap Test Data for HNS-IA at 1.55 g/cc; With Aluminum Attenuators.

TABLE 11 Proportional Gap Test Data for PETN Burlington Lot D471, at Density of 1.4 g/cc

Donor diameter, mils	Attenuator material	Mean sensitivity X, RDBg	Mean sensitivity X, PAlDBg and PStDBg	Std. Dev. σ, DBg	Std dev. of mean σ_X, DBg	Std dev of std. dev. σ_σ, DBg	Stimulus for 50%,[a] PAlDBg and PStDBg
50	Al 2011-0[b]	12 321	9 221[c]	0.135	0 041	0.047	9.293[c]
100	Al 2011-0[b]	8 558	8.458[c]	0.250	0.065	0 089	8 572[c]
200	Al 2011-T3[b]	5 243	8.077[c]	0 168	0 047	0 055	8.159[c]
50	Steel[d]	16.442	13 432	0 475	0.115	0 209	13 635
100	Steel, C1215[b]	11.442	11.426[c]	0 250	0 065	0.089	11 559[c]
200	Steel, C1215[b]	7 025	10 010[c]	0.163	0.045	0 053	10.090[c]

[a] Maximum at 95% confidence
[b] Bar stock, sliced in lathe
[c] Adjusted to equivalent for aluminum 1100-0 or low carbon shim steel
[d] Low carbon shim steel.

Example 1. Reliability Analysis of PBXN-5, Type I, Component

Assume we wish to prove 99.9% reliability at a 95% confidence level between two explosive components. the acceptor is to be loaded with PBXN-5, Type I, whose 50 and 99 9% initiation stimulus versus donor diameter is shown in Figure 27. the 50% plot is not needed for the evaluation and is only shown to indicate the relationship to the 99 9% curves. The explosive interface material is steel In testing the interface, it was found that Lot 135A is the *least* sensitive VARICOMP explosive that can be initiated with at least 50% reliability at 95% confidence This can be done by achieving initiation at least 5 times in 5 trials, 7 times in 8 trials, 9 times in 11 trials, etc. Since the curve for the VARICOMP explosive is at all points above and to the right of the 99 9% curve, the reliability of the interface is shown to be at least 99 9%.

Example 2. Reliability Analysis of Explosive "T" Component

If the slope for the design explosive is between those of the two VARICOMP series, it may be advantageous to use both series as shown in the following example.

Suppose an interface had been tested using VARICOMP explosives of each series as surrogates for the design explosive "T," the intended acceptor design explosive. Furthermore, the materials designated X358 and 135A are the least sensitive of their respective series that were initiated with at least 50% reliability at 95% confidence This can be done by achieving initiation at least 5 times in 5 trials, 7 times in 8 trials, or 9 times in 11 trials. In Figure 28, the estimate that the interface with an acceptor of X358 is more than 50% reliable indicates that the locus of the points defining the effective donor charge diameter and stimulus intensity is above and to the right of the curve AOB (the plotted data relating the minimum value, at 95% confidence, of the mean initiation stimulus to donor diameter for X358) Similarly the estimate for 135A indicates that the locus of these points is above and to the right of the curve COD When these indications are combined, the locus must be above and to the right of the curve AOD. Since this area is above the curve EF at all points (plotted data relating stimulus for which the predicted reliability of the design explosive "T" is at least 99.99% at 95% confidence to the donor diameter), it can be predicted that the detonation transfer reliability at the interface in question will be at least 99.99% at 95% confidence for any effective donor diameter.

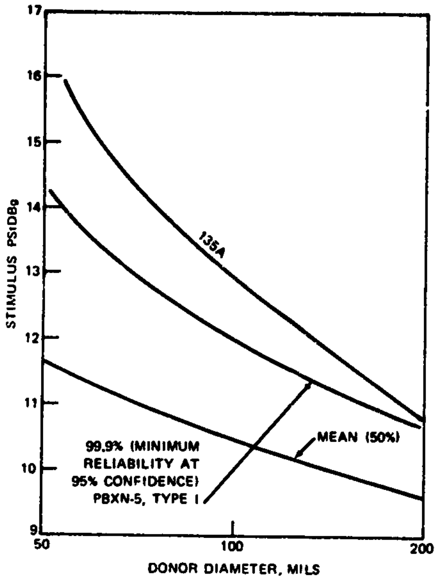


FIGURE 27. Example of Graphical Reliability Analysis for PBXN-5, Type I.

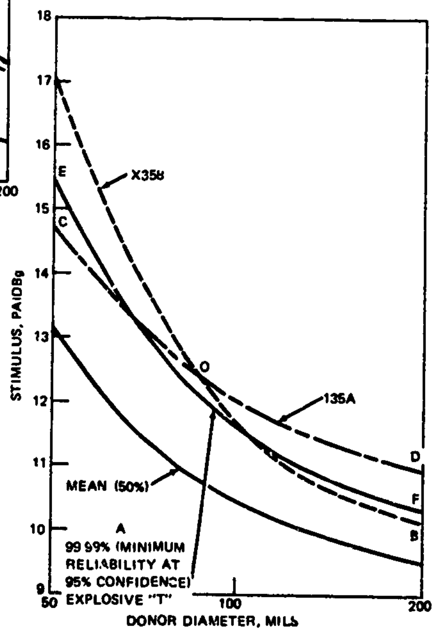
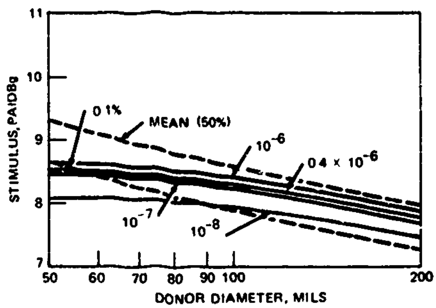


FIGURE 28. Example of Graphical Reliability Analysis for Explosive "T".

Example 3. Safety Analysis of PBXN-5, Type I, Component

To utilize PETN in safety evaluation of the explosive train, several procedures can be followed. Two of those procedures and sample evaluations are outlined below.

Out-of-line safety was demonstrated by a test program, including a progressive arming Bruceton and a two-level progressive arming rundown test, of the statistical design described in MIL-STD-331.[10] For these tests, the leads were loaded with PETN that was calibrated. As outlined in NAVORD Report 2101[11] the results of the Probit analysis of the progressive arming test data gave a "degree of safety" of 17 which corresponds with a safety failure probability of $10^{-4.9}$ Under conditions where the detonation transfer probability of PETN is 10^{-3} or less, that of PBXN-5, Type I, is less than 10^{-6} (Figure 29). The curve for 10^{-6} probability of detonation transfer of PBXN-5 is at all points above and to the right of the 10^{-3} probability of initiation for PETN.



—— MINIMUM RELIABILITIES (95% CONFIDENCE) (PAIDBg) FOR DETONATION TRANSFER TO PBXN 5, TYPE I, AT LOW (NEGATIVE EXPONENTIALS OF TEN) LEVELS

— — MAXIMUM RELIABILITIES (95% CONFIDENCE) FOR INITIATION OF PETN AT LEVELS GIVEN IN PERCENTAGES

FIGURE 29. Example of Safety Test Evaluation for PBXN-5, Type I, at 1.7 g/cc; With Aluminum Attenuators.

[10] MIL-STD-331. *Military Standard Fuze and Fuze Components, Environmental and Performance Tests for*, 16 April 1971.

[11] Naval Ordnance Laboratory *Statistical Methods Appropriate for Evaluation of Fuze Explosive-Train Safety Reliability*, by H. P Culling. White Oak, Md., NOL, October 1953.

Example 4. Safety Analysis of CH-6 Component

In the preliminary evaluation of the design concept of an explosive train with a steel rotor, the acceptor was an explosive lead loaded with CH-6 with a density of 1.7 g/cc. Out-of-line safety was to comply with the objective of MIL-STD-1316A,[12] which states that the safety failure rate must not exceed 10^{-6} All five trials with PETN were "safe" as defined in Test 115, MIL-STD-331[10] It is determined from Table 12 that 5/5 safety score indicates that the safety failure rate for PETN is less than 45.06% Figure 30 shows that, under conditions where PETN is initiated half the time or less, the probability of detonation transfer to CH-6 is less than 10^{-6} Again all points of the probability of detonation of the CH-6 curve for 10^{-6} are above and to the right of the 50% probability of initiation curve for PETN.

The general step-by-step procedure to be used in evaluating the reliability of the interface is as follows

1 Assume the acceptor explosive at the interface in question is CH-6, PBXN-5, or HNS-IA. Match the slopes of one of the two VARICOMP series with the design explosive with the proper barrier material and density

2. Determine the reliability of the interface desired. This is normally dependent upon the desired overall reliability of the complete system and is generally expected to be 99.99% at 95% confidence

3. With a few preliminary tests using the VARICOMP series selected in place of the design explosive, determine the least sensitive VARICOMP explosive that can be initiated. Start with the least sensitive (highest percentage of desensitizing material), and if that cannot be initiated, go to the next least sensitive, etc

4. Perform a number of tests utilizing the particular VARICOMP series and percentage desensitized chosen in step 3 The number of tests performed is dependent upon the users application; if a "quick look" at a new interface is desired, two or three tests may be adequate, but for determining reliability of a production type item, 20 or 30 tests may be desirable

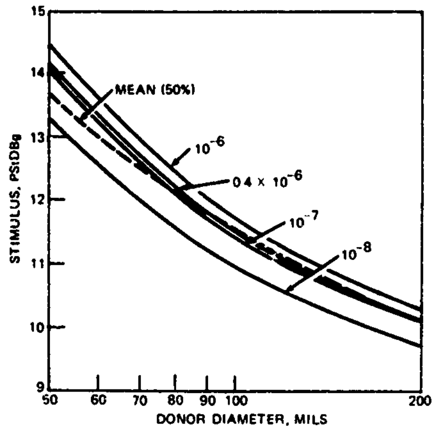
5. If the number of fires in the tests of step 4 is shown to be at least 50% at 95% confidence by utilizing binomial statistics of Table 12 (examples are 12, 13, 14, or 15 fires in 15 tests), and the curve relating stimulus to donor diameter for the particular VARICOMP series is at all points above the similar curve for the design explosive at the reliability desired, the reliability of the interface has been shown to be at least that good

[12] MIL-STD-1316A *Military Standard, Fuze, Design Safety, Criteria for*, 17 September 1970.

TABLE 12. 95% Confidence Single-Sided Estimate Lower Limit of the Reliability, L^R, for Sample Sizes of 20 or Less.

Reliability entries are expressed in percent.

Trial \ Successes	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	5.00																			
2	2.54	22.37																		
3	1.70	13.53	36.86																	
4	1.27	9.77	24.88	47.28																
5	1.02	7.65	18.94	34.25	54.94															
6	0.85	6.29	15.31	27.14	41.81	60.67														
7	0.73	5.34	12.88	22.52	34.11	47.92	65.18													
8	0.64	4.64	11.11	19.28	28.94	40.00	52.95	68.79												
9	0.57	4.11	9.77	16.89	25.13	34.48	45.02	57.06	71.71											
10	0.51	3.68	8.73	14.99	22.26	30.38	39.33	49.32	60.56	74.13										
11	0.46	3.33	7.87	13.51	19.98	27.10	35.00	43.57	53.00	63.53	76.18									
12	0.43	3.04	7.19	12.28	18.09	24.51	31.56	39.12	47.27	56.18	66.11	77.92								
13	0.39	2.81	6.60	11.27	16.56	22.39	28.74	35.52	42.76	50.51	58.98	68.34	79.41							
14	0.36	2.60	6.11	10.41	15.29	20.60	26.40	32.[illegible]3	39.06	45.98	53.40	61.44	70.35	80.74						
15	0.34	2.42	5.68	9.65	14.18	19.11	24.40	30.03	35.98	42.23	48.89	55.97	63.69	72.09	81.88					
16	0.32	2.27	5.31	9.03	13.20	17.79	22.65	27.87	33.33	39.15	45.12	51.61	58.35	65.57	73.60	82.94				
17	0.30	2.13	4.99	8.46	12.39	16.61	21.17	25.97	31.06	36.44	42.00	47.85	53.94	60.45	67.39	74.98	83.83			
18	0.28	2.01	4.70	7.97	11.64	15.64	19.89	24.43	30.00	34.07	39.23	44.59	50.19	56.11	62.29	68.95	76.23	84.67		
19	0.27	1.90	4.45	7.53	10.99	14.73	18.77	22.94	27.38	32.05	36.79	41.78	47.05	52.40	58.14	64.10	70.42	77.39	85.43	
20	0.26	1.81	4.21	7.14	10.41	13.94	17.73	21.70	25.86	30.21	34.70	39.41	44.22	49.26	54.47	59.93	65.59	71.77	78.38	86.10



MINIMUM RELIABILITIES (95% CONFIDENCE) (PS:DBg) FOR DETONATION TRANSFER TO CH-6 AT LOW (NEGATIVE EXPONENTIALS OF TEN) LEVELS

MAXIMUM RELIABILITIES (95% CONFIDENCE) FOR INITIATION OF PETN AT LEVELS GIVEN IN PERCENTAGES

FIGURE 30. Example of Safety Test Evaluation for CH-6 at 1.7 g/cc, With Steel Attenuator.

Appendix A

DETAILS OF CALIBRATION SYSTEM COMPONENTS

This section contains detailed sketches (Figures A-1 through A-11) of components used in the calibration system. See also Figures 1, 5, and 6

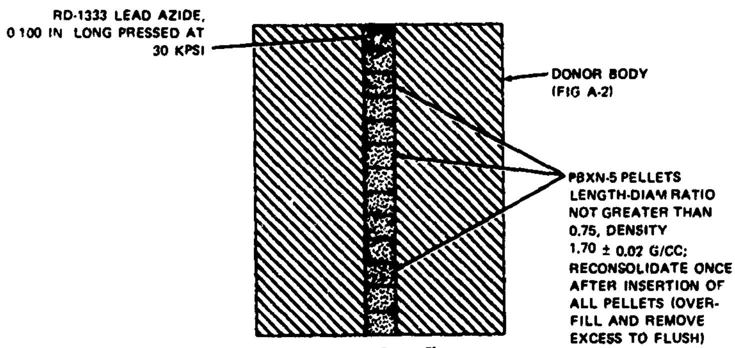
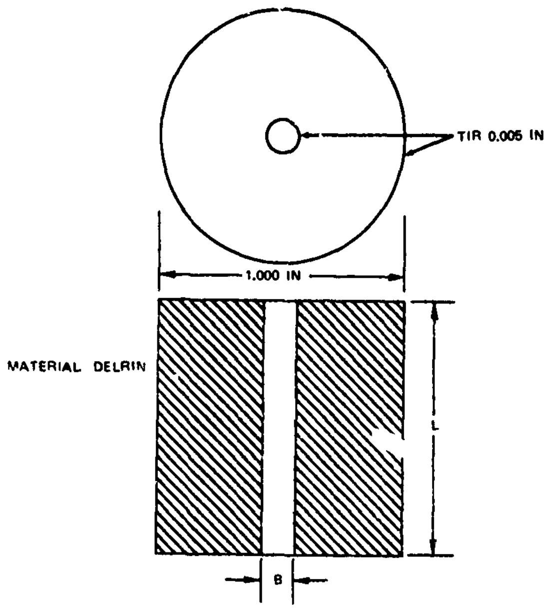
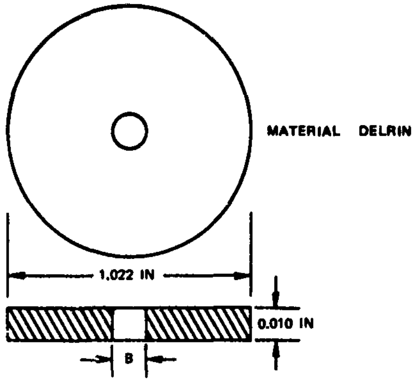


FIGURE A-1. Donor Charge.



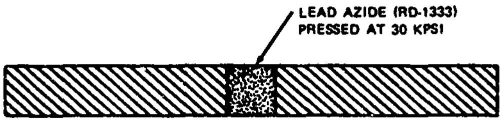
ITEM	LENGTH (L), IN (FIG A-1)	HOLE DIAMETER (B), IN	DRILL	LENGTH (L), IN (FIG 3)
1	0.55	0.050	1.25 MM	0.45
2	0.9	0.100	#39	0.8
3	1.6	0.200	#8	1.5

FIGURE A-2. Donor Body.



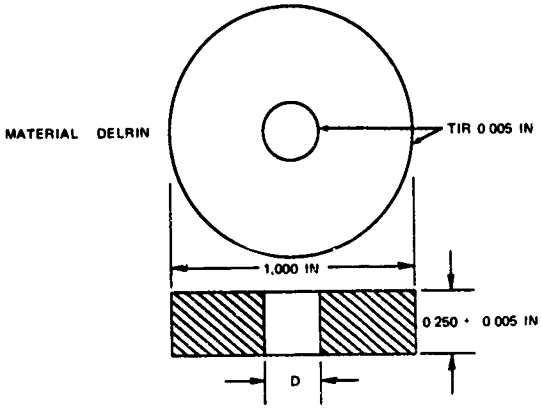
ITEM	HOLE DIAMETER (B), IN	DRILL
1	0.050	1.25 MM
2	0.100	#39
3	0.200	#8

(a) Donor Initiator



(b) Donor Body.

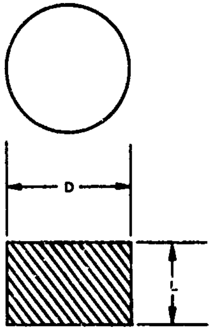
FIGURE A-3. Donor Initiator and Body.



ITEM	DIAMETER (D), IN	DRILL
1	0 0995	#39
2	0.201	#7
3	0 404	Y

FIGURE A-4 Acceptor Holder.

MATERIAL AND DENSITY OR LOADING PRESSURE
AS SPECIFIED FOR TEST. DENSITY TO BE
MEASURED AND RECORDED



ITEM	DIAMETER (D), IN	LENGTH (L), IN
1	0.099 $^{+0.000}_{-0.001}$	0.086 ± 0.001
2	0.199 $^{+0.000}_{0.002}$	0.130 ± 0.002
3	0.399 $^{+0.000}_{-0.004}$	0.260 ± 0.004

FIGURF A-5. Acceptor Pellet.

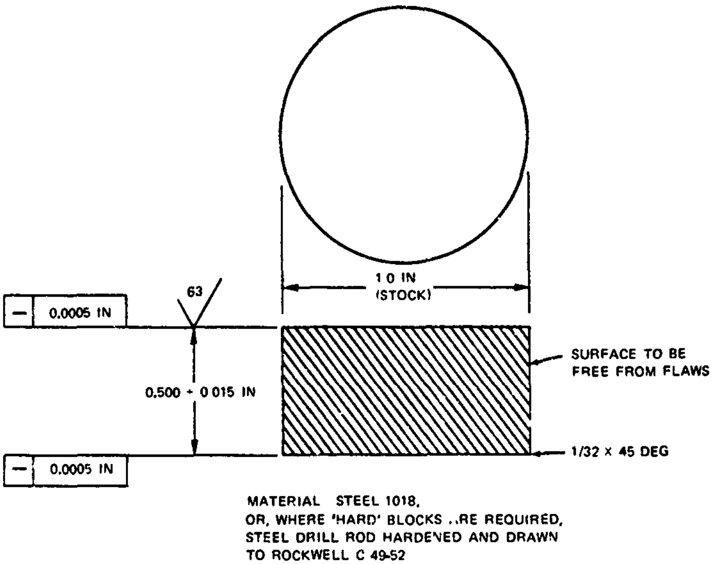


FIGURE A-6. Dent Block.

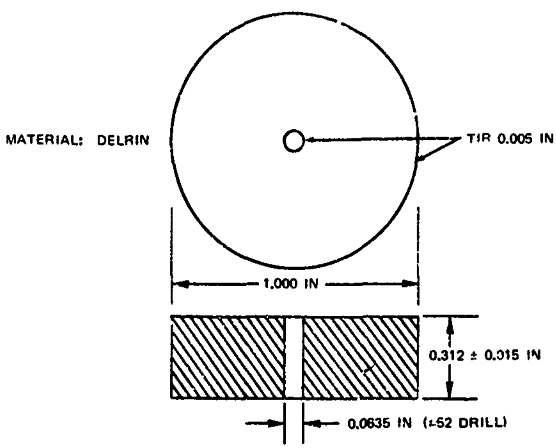


FIGURE A-7. Electrode Guide.

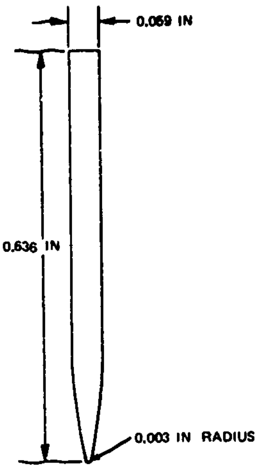


FIGURE A-8 Electrode (Steel Phonograph Needle).

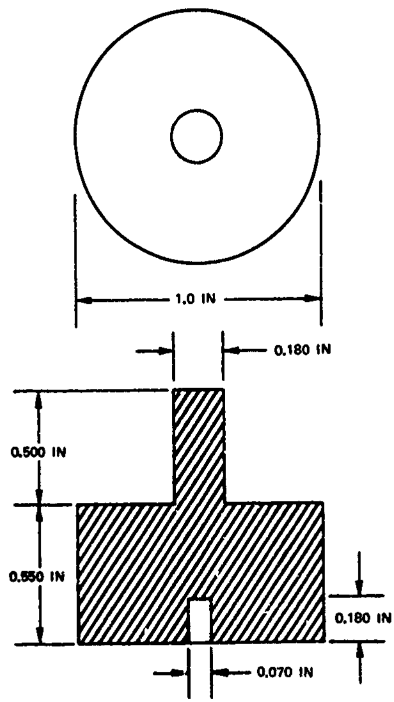


FIGURE A-9. Connector.

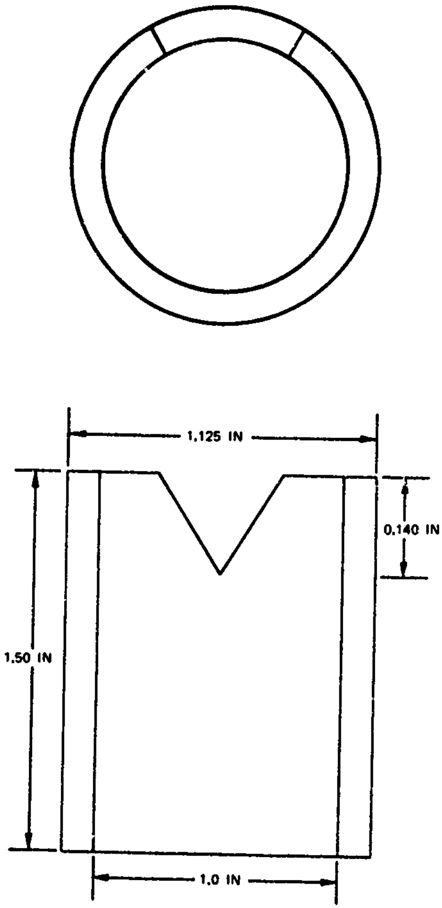
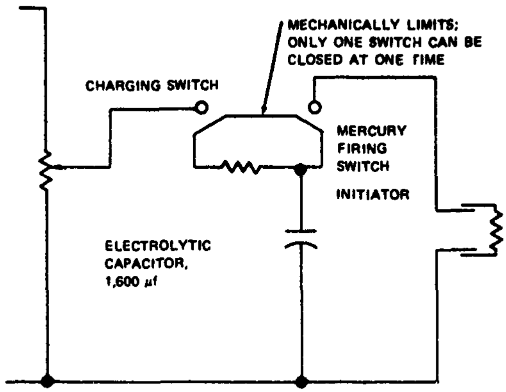


FIGURE A-10. Centering Sleeve (Polyethylene Tubing).



FIGURF A-lL Pulse Fnng Test Circuit.

Appendix B

LOGISTIC ANALYSIS DATA

This appendix contains the logistic analysis data (Tables B-1 through B-12) obtained from all calibration of both types of VARICOMP and the design explosives The technique for using the logistic reliability and safety analysis is the same as that described under "Use of Data" for the assumed normal distribution

TABLE B-1. Logistic Analysis for HNS-IA.

Donor diameter, mils	Attenuator material	Acceptor density nominal, g/cc	Mean sensitivity X, PAIDBg	Estimate of gamma, g	Variability of estimate of mean, S_m	Variability of estimate of gamma, S_g	Stimulus for 99%,[a] PAIDBg	Stimulus for 99.9%,[a] PAIDBg	Stimulus for 99.99%,[a] PAIDBg
50	Al	1.40	11.165	0.0670	0.0337	0.0296	12.3560	12.8962	13.5449
100	Al	1.40	10.5583	0.1207	0.0552	0.0447	11.5708	12.0293	12.4868
200	Al	1.40	9.985	0.1400	0.0621	0.0542	10.5817	10.8649	11.1381
50	Al	1.55	11.2317	0.1956	0.0824	0.0823	12.9398	13.7225	14.5036
100	Al	1.55	10.3583	0.0908	0.0448	0.0305	11.1007	11.4331	11.7648
200	Al	1.55	9.9500	0.0902	0.0437	0.0339	10.7149	11.0595	11.4034

[a] Minimum at 95% confidence

TABLE B-2. Logistic Analysis for PBXN-5, Type II.

Donor diameter, mils	Attenuator material	Acceptor density nominal, g/cc	Mean sensitivity X, PAIDBg	Estimate of gamma, g	Variability of estimate of mean, S_m	Variability of estimate of gamma, S_g	Stimulus for 99%,[a] PAIDBg	Stimulus for 99.9%,[a] PAIDBg	Stimulus for 99.99%,[a] PAIDBg
50	Al	1.7	15.7817	1.0382	0.4508	0.6803	26.9412	32.1254	37.2983
100	Al	1.7	11.1679	0.2041	0.0885	0.0895	12.9653	13.7865	14.6060
200	Al	1.7	14.8938	0.2143	0.0924	0.0953	12.2131	13.0964	13.9778
50	Al	1.8	14.8938	0.4911	0.2163	0.2363	19.4772	21.5786	23.6756
100	Al	1.8	11.5083	0.2489	0.1018	0.1120	13.7413	14.7694	15.7952
200	Al	1.8	9.835	0.1071	0.0503	0.0386	10.7295	11.1327	11.5352

[a] Minimum at 95% confidence

TABLE B-3. Logistic Analysis for PBXN-5, Type I.

Donor diameter, mils	Attenuator material	Acceptor density nominal, g/cc	Mean sensitivity X, PAIDBg	Estimate of gamma, g	Variability of estimate of mean, S_m	Variability of estimate of gamma, S_g	Stimulus for 99%,[a] PAIDBg	Stimulus for 99.9%,[a] PAIDBg	Stimulus for 99.99%,[a] PAIDBg
50	Al	1.8	11.80	0.149	0.0654	0.0572	12.61	13.10	13.65
100	Al	1.8	10.91	0.1952	0.0823	0.0822	12.06	12.82	13.69
200	Al	1.8	10.09	0.107	0.0502	0.0388	10.64	10.95	11.25
50	St	1.8	16.34	0.1735	0.0769	0.0817	17.39	18.09	18.91
100	St	1.8	14.36	0.1595	0.0716	0.0654	15.25	15.81	16.45
200	St	1.8	13.71	0.0446	0.0238	0.0254	13.94	14.07	14.21
50	Al	1.7	11.62	0.1785	0.0789	0.075	12.74	13.21	13.67
100	Al	1.7	10.41	0.0942	0.0448	0.036	10.89	11.17	11.47
200	Al	1.7	9.64	0.0918	0.044	0.035	10.10	10.37	10.66
50	St	1.7	15.38	0.1174	0.0671	0.0424	16.00	16.34	16.73
100	St	1.7	14.36	0.1595	0.0716	0.0654	15.25	15.81	16.45
200	St	1.7	13.34	0.0898	0.0461	0.0313	13.79	14.04	14.31

[a] Minimum at 95% confidence

TABLE B-4. Logistic Analysis for CH-6.

Donor diameter, mils	Attenuator material	Acceptor density nominal, g/cc	Mean sensitivity X, PAIDBg	Estimate of gamma, g	Variability of estimate of mean, S_m	Variability of estimate of gamma, S_g	Stimulus for 99%,[a] PAIDBg	Stimulus for 99.9%,[a] PAIDBg	Stimulus for 99.99%,[a] PAIDBg
50	Al	1.6	23.86	1.545	0.6721	1.7024	100.00	100.00	100.00
100	Al	1.6	11.13	0.204	0.0884	0.1468	12.86	14.30	16.13
200	Al	1.6	9.89	0.0957	0.0477	0.0406	10.40	10.69	11.02
50	St	1.6	27.66	0.24	0.0987	0.014	29.17	30.22	31.45
100	St	1.6	15.62	0.25	0.1059	0.1166	17.28	18.51	19.94
200	St	1.6	13.53	0.0461	0.0252	0.021	13.75	13.88	14.02
50	Al	1.7	16.65	0.7289	0.272	0.4921	28.80	41.41	58.34
100	Al	1.7	11.22	0.149	0.0678	0.0595	12.04	12.54	13.11
200	Al	1.7	9.90	0.0605	0.0307	0.0294	10.21	10.39	10.59
50	St	1.7	22.17	0.47	0.1893	0.2679	26.97	31.28	36.89
100	St	1.7	15.29	0.3075	0.1278	0.1535	17.57	19.34	21.54
200	St	1.7	13.74	0.0605	0.0307	0.0294	14.05	14.23	14.43

[a] Minimum at 95% confidence

TABLE B-5. Logistic Analysis for VARICOMP Lot 135A

Donor diameter, mils	Attenuator material	Mean sensitivity X, PAIDBg and PStDBg	Estimate of gamma, g	Variability of estimate of mean, S_m	Variability of estimate of gamma, S_g	Stimulus for 99%,[a] PAIDBg and PStDBg	Stimulus for 99.9%[a] PAIDBg and PStDBg	Stimulus for 99.99%,[a] PAIDBg and PStDBg
50	Al	16.04	0.4082	0.1659	0.2256		18.32	27.17
100	Al	12.14	0.4468	0.1872	0.2656		16.78	26.46
200	Al	11.05	0.3023	0.1258	0.150		13.27	17.10
50	St	21.33	0.2378	0.0979	0.105	22.84	23.88	25.12
100	St	16.26	0.3380	0.1393	0.1707	18.69	20.98	23.60
200	St	15.08	0.096	0.0467	0.0335	15.56	15.84	16.14

[a] Minimum at 95% confidence

TABLE B-6. Logistic Analysis for Varicomp Lot 135B

Donor diameter, mils	Attenuator material	Mean sensitivity X, PAIDBg and PStDBg	Estimate of gamma, g	Variability of estimate of mean, S_m	Variability of estimate of gamma, S_g	Stimulus for 99%,[a] PAIDBg and PStDBg	Stimulus for 99.9%[a] PAIDBg and PStDBg	Stimulus for 99.99%,[a] PAIDBg and PStDBg
50	Al	14.76	0.0785	0.0399	0.0321	15.16	15.39	15.63
100	Al	12.62	0.1735	0.0767	0.0731	13.62	14.26	14.99
200	Al	10.68	0.0357	0.202	0.0234	10.87	10.98	11.09
50	St	19.83	0.0964	0.0462	0.0337	20.32	20.59	20.89
100	St	16.65	0.2054	0.0890	0.0902	17.90	18.74	19.73
200	St	14.54	0.0819	0.0411	0.0297	14.95	15.18	15.42

[a] Minimum at 95% confidence

TABLE B-7. Logistic Analysis for VARICOMP Lot 135E.

Donor diameter, mils	Attenuator material	Mean sensitivity X, PAlDBg and PStDBg	Estimate of gamma, g	Variability of estimate of mean, S_m	Variability of estimate of gamma, S_g	Stimulus for 99%,[a] PAlDBg and PStDBg	Stimulus for 99.9%,[a] PAlDBg and PStDBg	Stimulus for 99.99%,[a] PAlDBg and PStDBg
50	Al	19.55	0.3672	0.1517	0.1377	21.96	23.06	25.70
100	Al	13.01	0.3822	0.1507	0.1991	16.22	18.89	22.27
200	Al	11.27	0.0872	0.0450	0.0383	11.73	11.99	12.29
50	St	23.35	0.1489	0.0653	0.0577	24.16	24.65	25.21
100	St	18.54	0.1886	0.0799	0.0794	19.62	20.37	21.20
200	St	15.18	0.1937	0.0847	0.0845	16.34	17.11	18.00

[a] Minimum at 95% confidence

TABLE B-8. Logistic Analysis for RDX/Calcium Stearate NOL No. X-353

Donor diameter, mils	Attenuator material	Mean sensitivity X, PAlDBg and PStDBg	Estimate of gamma, g	Variability of estimate of mean, S_m	Variability of estimate of gamma, S_g	Stimulus for 99%,[a] PAlDBg and PStDBg	Stimulus for 99.9%,[a] PAlDBg and PStDBg	Stimulus for 99.99%,[a] PAlDBg and PStDBg
50	Al	15.38	0.382	0.092	0.188	18.42	20.91	24.02
100	Al	11.24	0.093	0.027	0.032	11.72	11.98	12.27
200	Al	9.735	0.14	0.036	0.048	10.46	10.89	11.36
50	St	20.73	0.362	0.087	0.176	23.52	25.75	28.54
100	St	15.36	0.149	0.039	0.053	16.15	16.62	17.14
200	St	13.53	0.088	0.025	0.029	13.96	14.20	14.46

[a] Minimum at 95% confidence

TABLE B-9. Logistic Analysis for RDX/Calcium Stearate NOL No. X358.

Donor diameter, mils	Attenuator material	Mean sensitivity X, PAlDBg and PStDBg	Estimate of gamma, g	Variability of estimate of mean, S_m	Variability of estimate of gamma, S_g	Stimulus for 99%,[a] PAlDBg and PStDBg	Stimulus for 99.9%,[a] PAlDBg and PStDBg	Stimulus for 99.99%,[a] PAlDBg and PStDBg
50	Al	18.40	0.3037	0.078	0.162	20.74	22.61	24.95
100	Al	11.59	0.0896	0.024	0.0296	11.71	12.28	12.54
200	Al	10.12	0.0452	0.015	0.033	10.37	10.52	10.70
50	St	25.29	0.156	0.04	0.057	26.08	26.62	27.20
100	St	15.99	0.032	0.01	0.0083	26.08	26.62	27.20
200	St	13.68	0.051	0.017	0.028	13.94	14.10	14.26

[a] Minimum at 95% confidence

TABLE B-10. Logistic Analysis for RDX/Calcium Stearate NOL No. X366.

Donor diameter, mils	Attenuator material	Mean sensitivity X, PAlDBg and PStDBg	Estimate of gamma, g	Variability of estimate of mean, S_m	Variability of estimate of gamma, S_g	Stimulus for 99%,[a] PAlDBg and PStDBg	Stimulus for 99.9%,[a] PAlDBg and PStDBg	Stimulus for 99.99%,[a] PAlDBg and PStDBg
50	Al	inf[b]						
100	Al	14.12	0.099	0.027	0.033	14.62	14.89	15.19
200	Al	10.91	0.0625	0.021	0.017	11.21	11.37	11.53
50	St	inf[b]						
100	St	20.50	0.265	0.067	0.117	22.02	23.25	24.72
200	St	14.86	0.068	0.022	0.031	15.19	15.39	15.56

[a] Minimum at 95% confidence

[b] Infinity, acceptor was not initiated without an attenuator

TABLE B-11. Logistic Analysis for RDX/Calcium Stearate NOL No. X374.

Donor diameter, mils	Attenuator material	Mean sensitivity X, PAIDBg and PStDBg	Estimate of gamma, g	Variability of estimate of mean, S_m	Variability of estimate of gamma, S_g	Stimulus for 99%,[a] PAIDBg and PStDBg	Stimulus for 99 9%,[a] PAIDBg and PStDBg	Stimulus for 99 99%,[a] PAIDBg and PStDBg
50	Al	inf [b]						
100	Al	16.43	0 237	0 063	0 105	17 92	18.96	20 20
200	Al	11 44	0 092	0 025	0 029	11 89	12 15	12 41
50	St	inf [b]						
100	St	22 36	0 266	0 068	0 117	24 08	25 32	26 80
200	St	15 74	0 162	0 155	0 059	16 65	17.18	17 78

[a] Minimum at 95% confidence

[b] Infinity, acceptor was not initiated without an attenuator

TABLE B-12 Logistic Analysis for PETN at Density of 1.4 g/cc.

Donor diameter, mils	Attenuator material	Mean sensitivity X, PAIDBg and PStDBg	Estimate of gamma, g	Variability of estimate of mean, S_m	Variability of estimate of gamma, S_g	Stimulus for 99%,[a] PAIDBg and PStDBg	Stimulus for 99 9%,[a] PAIDBg and PStDBg	Stimulus for 99 99%,[a] PAIDBg and PStDBg
50	Al	9 22	0 0817	0 025	0 028	9 62	9 85	10 09
100	Al	8 46	0 1489	0 038	0 053	9 25	9 72	10 24
200	Al	8.08	0 0943	0 026	0 031	8 55	8 81	9 08
50	St	13 43	0 2989	0 073	0 131	15.42	16 88	18 64
100	St	11 43	0 1489	0 038	0 053	12 22	12 69	13 21
200	St	10 01	0 0933	0 026	0 031	10 47	10 73	11 00

[a] Minimum at 95% confidence

Appendix C

PREPARATION OF VARICOMP MIXTURES WITH MINIMUM DEPENDENCY UPON DONOR DIAMETER

The RDX (2-micron)/calcium soap mixtures were prepared by four different methods The first two methods yielded poor and unduplicable results The following is an account of all methods used and an explanation of why the first two methods did not give satisfactory results.

Single-Step Continuous Flow Process

A continuous flow system (Figure C-1) was used to facilitate preparation of about 1,900 grams per batch Figures C-2 and C-3 show the Masterflex* pumps and the mixing nozzles

After calibrating the flow rate of the three pumps, adjustment was made of the concentration of (1) RDX dissolved in acetone, (2) sodium stearate dissolved in water, and (3) calcium chloride dissolved in water to give the appropriate ratios of solutes in the merging flows to give the desired composition

The solutions were mixed in the following manner The RDX solution from one pump and the sodium stearate solution from another were forced into a mixing nozzle of Teflon (polytetrafloroethylene). The openings into the mixing nozzle from the two solutions were drilled off-center to generate a swirling motion From this point, the RDX/sodium stearate slurry entered another mixing nozzle, as described above, along with the calcium chloride solution. The precipitate was collected by filtration and washed several times with tap water.

The following chemicals and amounts were used to produce an RDX/calcium stearate (10.6%) mixture (1) 1,690 76 grams of RDX in 20 liters of boiling acetone, (2) 200.47 grams of sodium stearate in 48 liters of hot tap water (63 to 67°C), and (3) 133.65 grams of calcium chloride in 18 liters of cold tap water.

This process involves the precipitation of RDX in the hot sodium stearate solution rather than cold water It was hoped that the rapid mixing and the higher temperature would produce very fine particles

Test results produced a far too sensitive mixture (only 3.5% calcium stearate), and the most suspect element was the sodium stearate solution. The turbidity of the sodium stearate solution (in hot tap water) indicated that it did not dissolve completely. Hence, it was decided to search for another desensitizer that would be more soluable in water.

*Registered trademark.

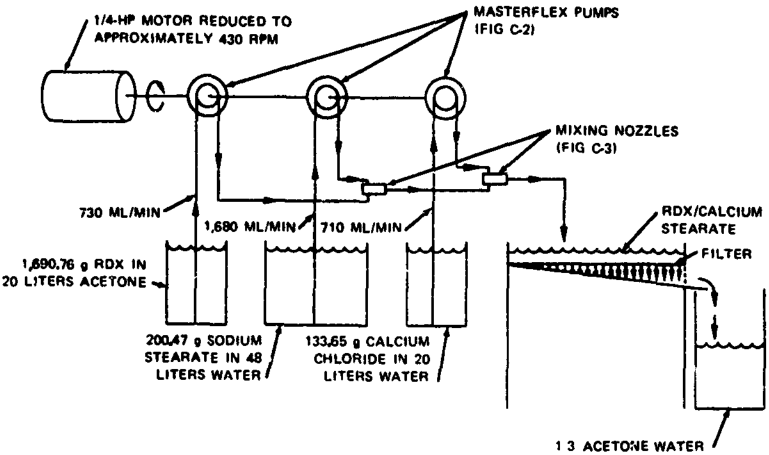


FIGURE C-1. Single-Step Continuous Flow System.

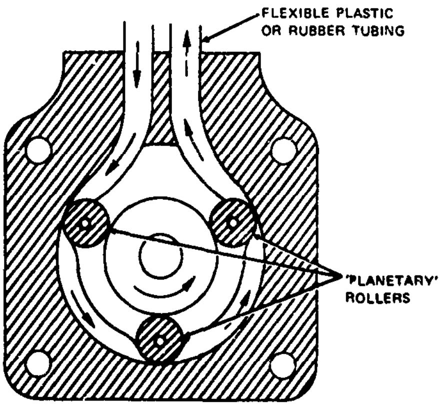


FIGURE C-2. Masterflex[r] Tubing Pump.

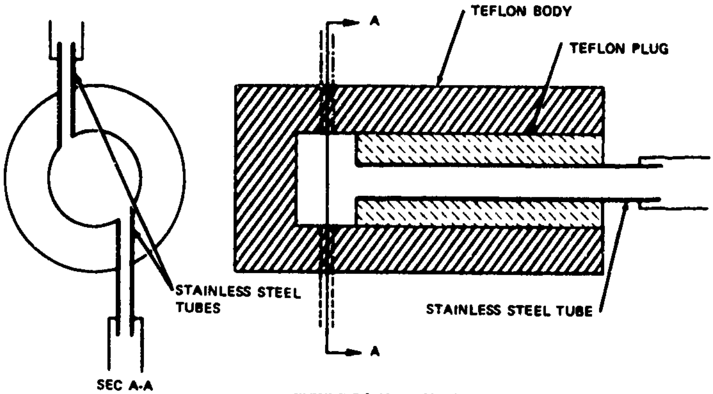


FIGURE C-3. Mixing Nozzle

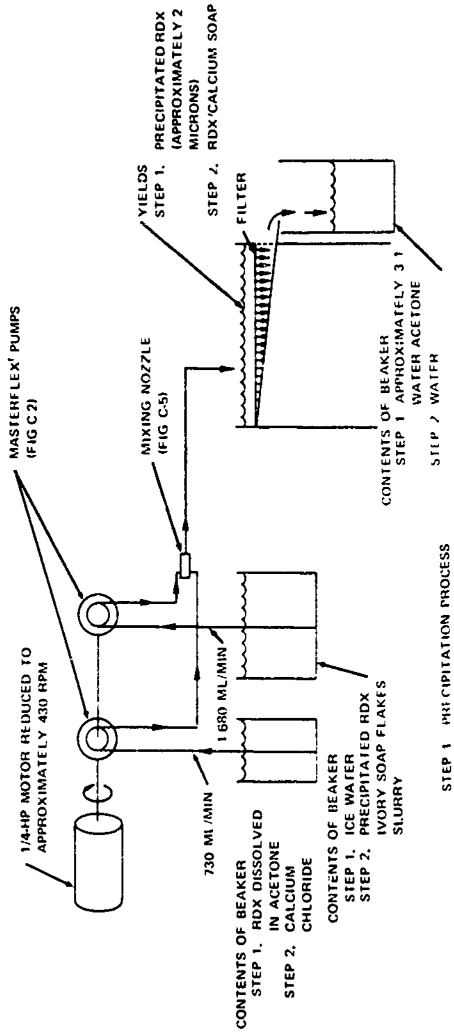
The search started and ended with the acquisition of Ivory Soap Flakes. The solution properties proved to be good, plus the fact that Ivory Soap Flakes are readily available and quite inexpensive.

The preparation was then tried by substituting Ivory Soap Flakes for sodium stearate. The product had a more satisfactory soap content (7 to 9%) and the sensitivity did decrease, but the batch was not acceptable with the 200-mil-diameter donors. The failure of the material in the respect was attributed to its coarser particle size that, in turn, was ascribed to the precipitation of the RDX in the hot soap solution rather than cold water.

Two-Step Continuous Flow Process

A two-step operation was used to reduce particle size. The RDX was dissolved in acetone (1,690.76 grams in 20 liters of acetone) and instead of recrystallizing the RDX with the hot soap solution, it was recrystallized with ice water using a similar continuous flow with two pumps and a mixing nozzle (Figure C-4). In the first step the apparatus was arranged to mix one part of the acetone solution of RDX with two parts of ice water (2 to 6°C). The precipitate was filtered and washed and added to the soap solution (200 grams of Ivory Soap Flakes in 48 liters of hot (63 to 67°C) tap water) after the supernatant fluid had drained off and before the precipitate had dried. The recrystallized RDX was added to the Ivory Soap Flakes solution and stirred vigorously. In the second step it was run through the apparatus again and mixed with the calcium chloride solution (133.65 grams in 18 liters of water). Again it was filtered and washed.

The resulting material was significantly finer than that made by the single-step process and proved to be insensitive enough to the 200-mil-diameter donors and sensitive enough to the 50-mil-diameter donors to be acceptable.



STEP 1 PRECIPITATION PROCESS
STEP 2 DESENSITIZATION PROCESS

FIGURE C-4. Two-Step Continuous Flow System.

Three batches were successfully made by this procedure, but duplication of these results was unsuccessful because of mechanical failures such as bursting of the flexible tubing, leaks, and breaks at joints, and erratic pumping rates. These failures were traced to stoppage of flow by premature crystallization of the RDX Some of the stoppages, which occurred at joints in the tubing, were apparently the result of cooling of the acetone solution of RDX. Most occurred at the point where the solution entered the chamber of the mixing nozzle and were ascribed to a combination of the cooling action of the ice water and possible penetration of the water, by diffusion or turbulence, into the mouth of the tube through which the acetone entered the chamber

Such stoppages were eliminated by reducing the RDX concentration in the acetone and modifying the mixing nozzle as shown in Figure C-5 so that the mixing process takes place in a parallel rather than swirling flow

Preparation of Lot 135A

The following procedure for Lot 135A was most successful for RDX with 10 6% calcium soap desensitizer

1 Dissolve 1,126 67 grams of RDX in 20 liters of boiling acetone (56 33 grams per liter)

2 Precipitate RDX with ice (2 to 6°C) water (2 1 water/RDX solution) by using the continuous flow system (Figure C-4) Filter recrystallized RDX

3 Dissolve 133.59 grams of Ivory Soap Flakes in 48 liters hot (63 to 67°C) tap water (2 78 grams per liter)

4 Mix the recrystallized RDX in the Ivory Soap Flakes solution.

5 Dissolve 89 04 grams of calcium chloride in 20 liters of tap water (4.45 grams per liter)

6 Mix RDX/Ivory Soap Flakes slurry with calcium chloride solution in continuous metered flow mixing apparatus (Figure C-4).

7 Filter, drain, and wash with five changes of water Dry

Preparation details for Lot 135A are given in Table C-1

Preparation of Lot 153B

Lot 135B was produced approximately in accordance with the procedures for 135A, with an intended calcium soap content of 5 3% As with Lot 135A, a number of batches were prepared, some were analyzed and subjected to microscopic examination, and each was subjected to screening tests. Preparation details are given in Table C-2.

Preparation of Lot 135C

Lot 135C was produced next, with a RDX/2 65% calcium soap content The production procedure was the same as for Lot 135B, and these amounts of chemicals were used in each batch: (1) 839.55 grams of RDX in 20 liters of acetone, (2) 22 85 grams of Ivory Soap Flakes in 48 liters of water and (3) 15 23 grams of calcium chloride in 20 liters of water After a number of screening tests, it was decided that the sensitivity of this material was too high to be useful, and the calibration of 135A indicated the need for a less sensitive material

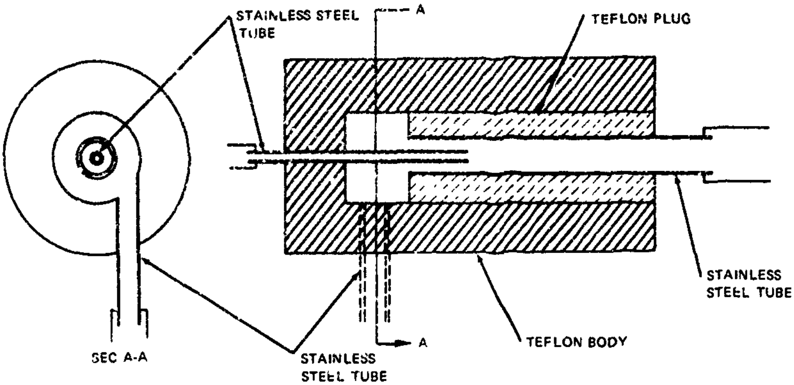


FIGURE C-5 Mixing Nozzle Modified for Parallel Flow

TABLE C-1 Preparation Details for RDX/Calcium Soap Lot 135A

Acceptance criteria 200 mil-diameter donor, >8 00 RDBg, 50-mil diameter donor <19 25 RDBg

Batch no	Yield		Screening test results, mean RDBg, Al attenuators	
	g	%	200 mil diameter donor	50 mil-diameter donor
135A 4A 11[a]	1 584 8	83 8	8 50	18 62
135A-4C 11[a]	1 253 7	66 3	8 12	19 12
135A 5B 11[a]	1 443 3	76 3	8 12	18 87
135A-6C 11[b]	1 315 9	104 4	8 25	18 50
135A 6C 12[b]	1,231 1	97 7	8 37	18 75
135A-6D 11[b]	945 2	75 0	8 37	18 75
135A-6D 12[b]	1,199 9	95 2	8 25	18 62
135A 6E 11[b]	1,160 3	92 1	8 25	18 37
135A 7B 11[b]	1,443 3	114 5	8 12	18 87
135A composite[c]	11,577 54		mean 8 1428 std dev 0 50	mean 19 0536 std dev 0 6625

[a] Ingredient quantities
1690 76 g RDX/20 liters acetone
200 47 g Ivory Soap Flakes/48 liters water
133 65 g calcium chloride/20 liters water

[b] Ingredient quantities
1126 67 g RDX/20 liters acetone
133 59 g Ivory Soap Flakes/48 liters water
89 04 g calcium chloride/20 liters water

[c] Percentage of calcium precipitate of Ivory Soap Flakes
11 174 (sample 1)
11 783 (sample 2)
11 812 (sample 3)
Av 11 589

Preparation of Lot 135D

The production procedure for Lot 135D was the same as for the other lots Since several batches of Lots 135A, 135B, and 135C were not usable but contained precipitated RDX of the appropriate particle size, some of this material was reclaimed for use in Lot 135D by the following procedure

TABLE C-2 Preparation Details for RDX/Calcium Soap Lot 135B

Acceptance criteria 200-mil-diameter donor, >7 50 RDBg, 50-mil-diameter donor, <18 25 RDBg

Batch no	Yields,		Screening test results, mean RDBg, Al attenuators	
	g	%	200-mil-diameter donor	50-mil-diameter donor
135B-7B 12[a]	955 0	80 0	7 37[d]	16 50
135B-7D-11[a]	1,103 7	92 8	7 87	17.12
135B-7D 12[b]	655 5	92 8	8 12	17 50
135B-7E 11[a]	1,117 8	94 1	8 00	17.62
135B-8E-11[b]	735 8	83 0	7 75	13 87
135B-8C 11[b]	735 8	83 0	7 37[d]	16 62
135B-8C-12[a]	962 2	81 0	7 62	17 62
135B-8D-11[a]	1,075 4	90 5	7 87	16 62
135B-8E 11[b]	679 2	76 6	8 37	17 62
135B-9A-11[b]	707 5	79 8	8 00	17 12
135B-9B-11[b]	707 5	79 8	8 37	16 87
135B-9B-12[b]	707 5	79 8	7 87	17.62
135B 9C-11[b]	933 5	105 3	8 00	17 37
135B-9D 12[c]	707 5	79 8	8 00	18 00
135B composite[e]	10,094	.	mean 7 7750 std dev 0 0875	mean 17 7679 std dev 0 1625

[a] Ingredient quantities
- 1126 67 g RDX/20 liters acetone
- 63 06 g Ivory Soap Flakes/48 liters water
- 42 04 g calcium chloride/20 liters water

[b] Ingredient quantities
- 839.55 g RDX/20 liters acetone
- 46.99 g Ivory Soap Flakes/48 liters water.
- 31.33 g calcium chloride/20 liters water

[c] Ingredient quantities.
- 839 55 g RDX/20 liters acetone
- 22 41 g Ivory Soap Flakes/48 liters water
- 14.94 g calcium chloride/20 liters water

[d] Failed screening test requirement.

[e] Percentage of calcium precipitate of Ivory Soap Flakes
- 5 7586 (sample 1)
- 5 3651 (sample 2)
- 5 6588 (sample 3)
- Av 5 5942

1 The concentration of the reclaimed VARICOMP explosive is ascertained by chemical analysis
2 An appropriate amount required to raise the soap content to 20% of Ivory Soap Flakes is dissolved in 48 liters of hot tap water.
3 The VARICOMP to be reclaimed is mixed in the soap solution to form a slurry
4 The calcium chloride is added to the slurry and mixed thoroughly.
5 The slurry is filtered, washed, and dried

Table C-3 lists the preparation details for Lot 135D

All batches of Lot 135D were blended together by mixing samples of each batch together and subjecting the composite sample to a screening test This sample, which was prepared by hand tumbling the subsamples after the material had been forced through a 16-mesh screen to break the lumps, met the criteria that had been established for Lot 135D.

Lot 135D was then blended by a "miller" (a Counter-Current Batch Mixer made by Posey Iron Works, Inc., Lancaster, Pa.), which mixes powder in a rotating bowl by the interaction of a steel roller, so mounted that its centerline is at right angles to and displaced horizontally from that of the rotating bowl and two vanes, one stationary and positioned to "plow" the powder from the sides and bottom corner of the bowl, and the other rotating (with its blade tangent to its rotary path) on the same center but the opposite direction of the bowl The miller, which had not beed used previously, was used because it seemed to break lumps more effectively and with less human effort than forcing through a sieve This mixing procedure apparently affects sensitivity since it resulted in a meterial that could not be initiated by means of the 50-mil-diameter donors even with no attenuator Since these indications that subtle modification of mixing techniques can substantially affect test results, it seemed probable that the material of Lot 135D might be saved

Analysis of composite Lot 135D showed it to have a soap content of about 22% rather than the 20% that had been intended. It has been observed, for some explosives, that an increase in density can increase sensitivity to small sources while decreasing sensitivity to larger sources With this in mind, an effort was made to find an additive that would result in increased density, relative to the theoretical maximum, at the loading pressure of 100,000 psi At this pressure, material from Lot 135D attained a density of about 96% of the theoretical maximum

To increase the relative density, a small amount of Vaseline petroleum jelly was added to a small sample drawn from Lot 135A. The relative density was increased, but the resulting pellets could not be initiated with the 50-mil-diameter donors

A small batch of material from Lot 135C, Lot 135D, and graphite proportional to yield a ratio of 80% RDX, 19.5% calcium soap and 0.5% graphite was mixed in the miller Material from this batch attained a density between 98 and 99% of the theoretical maximum, and more than passed the screening test On the basis of these results, it was decided to convert most of Lot 135D into Lot 135F, which has the above proportions, by adding material from Lot 135C Preparation details are given in Table C-4

TABLE C-3 Preparation Details for RDX/Calcium Soap Lot 135D.

Acceptance criteria 200-mil-diameter donor, >8.00 RDBg. 50-mil-diameter donor, <21.00 RDBg.

Batch no	Ingredient	Enhanced lot weight, g	Additional soap/$CaCl_2$ added, g	Yield		Screening test results, mean RDGb, Al attenuator	
				g	%	200-mil-diameter donor	50-mil-diameter donor
135D-11D-12[a]	...	...	...	1,188.6	97.5	8.37	20.87
135D-11E-11[a]	...	...	...	1,018.6	83.6	8.12	20.12
135D-12A-11[b]	enhanced Lot No. 135A	2,377 20	342.31/ 228.21	2,830 0	96	8.37	infinity
135D-12B-11	enhanced Lot No. 135B	2,136.65	426.92/ 280.29	2,405 5	94 1	8 67	infinity
135D-12C 11	enhanced Lot No. 135C	2,518.70	562.93/ 375.29	2,943.2	95 5	8 37	infinity
135D-12D-11	enhanced Lot No. 135C 135B	1,471.60 735 80	480.93/ 320.62	2,603 6	96 8	8 37	infinity
135D composite[c]	...	...	...	12,990	...	mean 8 1750 std dev 0 150	infinity ...

[a] Ingredient quantities

975.00 g RDX/20 liters acetone.
243.75 g Ivory Soap Flakes/48 liters water.
162 50 g calcium chloride/20 liters water

[b] One-half quantity used in 135D composite

[c] Percentage of calcium precipitate of Ivory Soap Flakes
20.371 (sample 1)
24.392 (sample 2)
22.009 (sample 3)

Av. 22.256

TABLE C-4. Preparation Details for RDX/Calcium Soap Lot 135E.

Acceptance criteria 200-mil-diameter donor, >8.12 RDBg, 50-mil-diameter donor, <23 25 RDBg

Batch no	Screening test results, mean RDGb, Al attenuators	
	200-mil-diameter donor	50-mil-diameter donor
135E-1[a]	8.37	22.50
135E 2[a]	8.12	21 75
135E 3[a]	8.50	22 00
135E 4[a]	8 37	23.00
135E 5[a]	8 25	22.50
135E 6[b]	8 25	23 00
135E composite[c] 11,057 g	mean 8.3583 std dev. 0 1375	mean 22.5625 std. dev 0.620

[a] Ingredient quantities

1,632 g 135D.
104 g 135C (6.7%)
132 g 135C (1 7%)
9 4 g Graphite (Dixon 620 – a product of the Joseph Dixon Crucible Co , Jersey City, N J)

[b] Ingredient quantities

1,454 0 g 135D
92 6 g 135C (6 7%)
115.0 g 135C (1 7%)
8.3 g Graphite (Dixon 620).

[c] Percentage of calcium precipitate of Ivory Soap Flakes

19.668 (sample 1)
19.711 (sample 2)
19 193 (sample 3)

Av. 19 523

Chemical Analysis of VARICOMP Mixtures

A chemical analysis of each of the various lots of RDX/calcium soap was performed as follows

1 Sample size is set to yield approximately 0.3 gram of calcium stearate after the extraction of the RDX From the standpoint of safety, an upper limit of 3- to 5-gram sample size is recommended.

2 A medium porosity sintered glass crucible is thoroughly washed and dried.

3 Weigh sample in sintered glass crucible

4. Extract RDX by 8 washings of 20ml each of boiling acetone. During each washing the sample is triturated continuously with a glass stirring rod in order to break up all lumps

5 The calcium stearate or calcium soap residue crucible is dried for 1 hour at 60°C.

6 The residue and crucible are weighted after being allowed to cool for 15 minutes The weight loss from the acetone extraction is the amount of RDX, and the weight of the residue is calcium stearate or calcium soap

Three samples from each lot were analyzed using this procedure and are shown in each of the tables for the various lots

Composition of Desensitizer in New VARICOMP Mixes

As has been mentioned in an earlier section, Ivory Soap Flakes was substituted for the sodium stearate, which had been used for similar purposes in earlier work,[9] because of its greater solubility in warm water (65°C) Sodium stearate is, of course, a soap Procter & Gamble Co. gave the following composition (in percent) for Ivory Soap Flakes

Tallow soap	>97
Fabric whitener	< 1
Perfume	< 1
Preservative	< 1
Glycerine	< 1
Silicates	< 1

The composition (in percent) of beef tallow is as follows [13]

Oleic acid (9 octadecanoic acid)	49 6
Palmitic acid (hexadecanoic acid)	27.4
Stearic acid (octadecanoic acid)	14 1
Linoleic acid (9, 12 octadecadienoic acid)	2.5
Myristic acid (tetradecanoic acid)	6.3

[13] Robert C. Weast, ed *Handbook of Chemistry and Physics*, 49th ed Cleveland, Ohio, Chemical Rubber Co., 1968